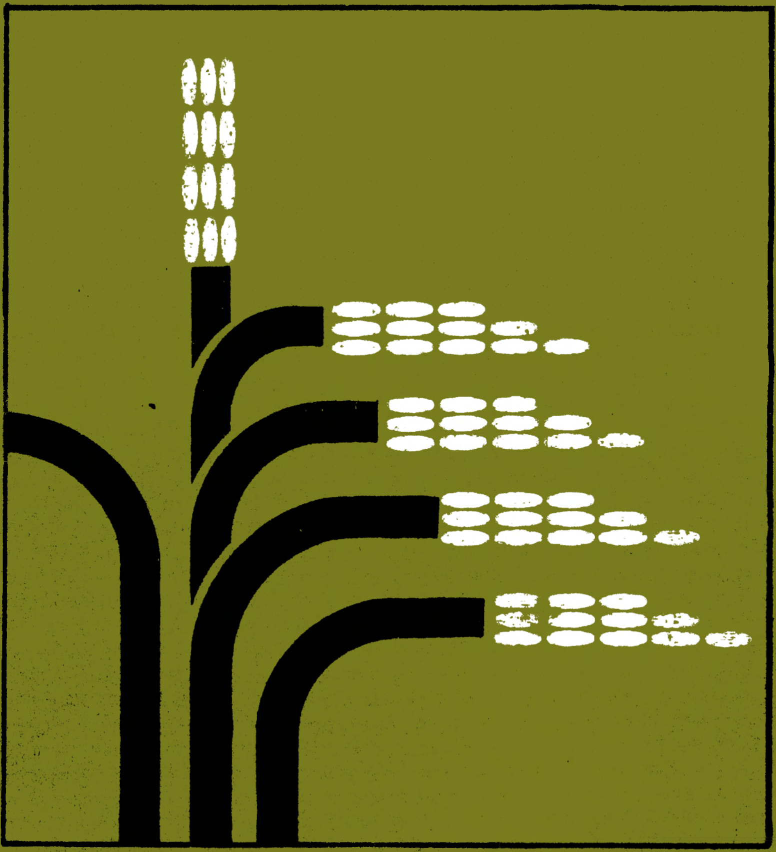
Rice Growing

V. KONOKHOVA



MIR PUBLISHERS

В. П. Конохова

Учебная книга рисовода

Издательство «Колос»
Москва

V. P. Konokhova

Rice Growing

Translated from the Russian
by
V. Kolykhmatov

Mir Publishers · Moscow

First published 1985
Revised from the 1982 Russian edition

На английском языке

Contents

Preface

Although rice may probably be a leading food crop in the world, in the Soviet Union it is a major crop in certain areas only. Rice has spread northward from the principal centers of its traditional cultivation to reach 47°N latitude, i.e. its northernmost biological boundary. But in spite of that, average yields and acreage in rice have increased and production of rice in this country promises to grow further through more efficient use of all the production variables, such as improved machinery and fertilizers, advanced cultivation practices, and superior varieties that will make obtainable an average of 7 tons per hectare of rough rice at a minimum cost.

The objectives in rice farming for the near future are to reach 3 million tons by 1985, and 3.3-3.5 million tons, by 1990.

We now think more often in terms of opening up new lands for rice and improving management of riceland already in use. The techniques of managing and improving rice production is really what this book is about. We need more skilled personnel for this new sector of agricultural production. The purpose of this textbook is to help build up numbers of trained men through specialized courses and trades schools, and home reading.

The *Rice Growing* is an attempt to provide both an easy text and useful reading for all those whom it may concern, be it an agricultural officer, an unskilled layman, a college student, a teacher or an experienced specialist.

The book is also an attempt to revise the latest data on production, yield, varieties, soil, fertilizer and water management practices, culture and control of weeds, diseases and pests of rice. The information was taken from the latest bulletins and current publications on the various aspects of rice varieties and culture.

The book does not cover each and everyone aspect of rice in detail, for it does not include breeding, genetics, chemistry of flooded soil, design and development of irrigation systems for rice production. It covers only that part of rice culture that may be of practical interest for the grower who would like to obtain how-to information. It does not cover the whole subject, it takes short-cuts, sometimes oversimplifies and often neglects to explain why one particular method is recommended. The justification for all this is that the book will be most useful if its main object is to be simple and practical. The subject is not directed at any examination syllabus, but would be a suitable guide for all those who are directly or indirectly involved in the growing of rice.

A Note on Terminology

When ideas are taken from one country to another, terms are likely to cause confusion. In order to avoid confusion with nomenclature, the following terms have been used throughout the text:

Check(-Basin) or *rice paddy* (not to be confused with paddy rice)	A flooded level basin usually rectangular in shape bordered by a dike or levee to retain water in which rice is grown
Large or *field check*	A large rectangular field section bordered by supply and waste ditches; may or may not be divided with cross levees into sub-fields, i.e. checks or rice paddies
Rough rice	Rice grain in the husk after threshing. Also known as paddy (rice)
Brown rice	Rice from which the husk only has been removed, but which still retains the bran layers and most of the germs. Also known as husked rice, cargo rice
Milled rice	Rice from which the husks (hulls), germ and bran have been removed by machinery. Also called polished rice, white rice

Milling of rice gives

Head rice	Whole-grain milled kernels
Second head rices	All broken kernels of large size
Screenings	All finer-sized broken kernels
"Brewer's" rice	All broken kernels of very fine size
Total milled rice or *milling yield*	Head rice and all sizes of broken kernels

INTRODUCTION

Rice, a leading cereal crop in many countries, is grown on all the continents. It is often considered to be a tropical crop although it is grown in the temperate zone in Asia, North America, and in the Southern part of Europe.

The distribution of rice through continents is uneven. About 91 percent of the world rice crop is grown in Asia; 5.8 percent in the two Americas; 2.8 percent in Africa; and 0.4 percent, in Europe.

Although all rice-growing countries have shown a definite upward trend in rice production during the past 25 years, the rates of increase have not been the same in each country. However, the world rice acreage and average yield have increased by 34 and 42 percent, respectively. The world acreage in rice increased from 133 million hectares in 1971 to 144 million hectares in 1981; average yield increased from 2.31 to 2.82 t/ha for the same period, respectively. The world total rice crop increased from 310 million tons in 1971 to 406.1 million tons in 1981.

Of the world's rice crop, about 26.1 million tons or 6.3 percent were produced in the developed countries, and 386.1 million tons or 93.7 percent, in the developing countries[1].

India has the largest acreages in rice, which account for almost 30 percent of the world rice acreage.

Rice turnover in the world trade is small. Rice export accounts for 3 to 5 percent of the annual world production of rice. In 1981, rice export exceeded 12 million tons. The major exporters are the USA (2.5 million tons) and Thailand (1.8 million tons). Total sales of rice from Australia, Italy, Japan, Burma, and Nepal vary from year to year and can make from 800 to 200 thou tons. The major importers are Indonesia, Korea, Iran, Hongkong, and Bangladesh.

---

[1] *FAO Monthly Bulletin of Statistics* 5, No. 12, 11-23 (1982).

Economic Value of Rice

By acreage and yield, among world cereals rice is a leading food crop cultivated for its edible starchy grain. It is the staple food for almost half of the world population, and an essential source of human subsistence in South and Southeast Asia where the average annual consumption of rice per capita is about 100 kg.

It hardly seems possible to overestimate the importance of rice for the peoples of those regions. The ancient Indian name for rice, dhanya, meaning 'sustainer of the human race', indicates its age-old importance.

The usefulness of rice is indeed universal because man benefits not only from its starchy grain for food, but also from other parts of the plant, and the by-products of its processing.

The grain with the hull, bran and germ removed by milling is used in dry cereals (head rice). The total yield of milled rice of home rices varies from 67 to 72 percent, and the energy of 100 g of milled kernels equals 359 calories. The dry matter of milled rice contains 88 percent starch (basically amylose and amylopectin), 6 to 8 percent protein, 0.5 percent fats, and 0.5 percent sugars. Because of its high digestibility (98 percent) and high nutritive value, white rice has become indispensable for use in baby and breakfast foods, and in diets for the sick. Cooked rice is highly regarded by many peoples and with some, table rices often replace bread. Rice is also used for the production of starch, alcoholic beverages and soft drinks. Rice flour contains little or no gluten but may be used as a blender in baking wheaten (white) bread, and in biscuits.

Rice hulls and polish that include bran, aleurone layer and the germ are used in the pharmaceutical industry for the production of phytin and vitamin B (thiamine, riboflavin, niacin). The germ rich in fats is a good source of butter and rice oil used in the manufacture of soap and candle sticks. Rice bran and polish are fed to farm animals. It is also used for the production of high-quality rice oil used in medicine, and in corrosion-resistant coatings. Broken rice or second head rice is used by the canning industry for human food, and for making alcoholic beverages, rice wine and bear specialities (brewer's rice). The brokens and screenings are a good source of starch whose yield ranges from 85 to 95 percent. Rice starch is also used in face powders.

Over 30 different useful articles and materials can be made from rice chaff. For one, the feed-grade yeast is the most valuable product for livestock. Chemical processing of rice chaff gives furfural which is a basic raw material for the manufacture of plastics. Cardboard pressed from

rice chaff is a fairly good construction material. Chaff char is an indispensable substitute for bone char in sugar refining.

Although rice straw is very coarse and therefore inferior in palatability, its nutritive value is much superior to the straw of other (winter) grain crops. When processed and flavored with grain concentrates, rice straw may be fed to farm animals, constituting almost half of their daily ration. Rice straw contains 1 percent protein, 0.5 percent fats, and 30 percent carbohydrates. Straw of the rice that is cut by direct combining is most valuable and, when conserved in a mixture with green peas or alfalfa, can make a fairly good feed for cattle.

Rice straw is a valuable raw material for the manufacture of high-quality paper. Other products made from rice straw include cardboards, ropes, packing material, rayon, linoleum, handbags, floor mats and rugs, hats and sandals, sacks and baskets, brooms and many other household articles. In Asia, rice straw is used for thatching roofs, for fuel and soil mulches. Rice straw may be used as fertilizer: 1 ton of rice straw contains 8 kg nitrogen, 1 kg phosphorus (P_2O_5), and 12 kg potassium (K_2O).

Rice in this country is cultivated exclusively under irrigation. Its yield almost never depends on the whim of the weather and is maintained sufficiently high and stable even in dry years. Growing rice facilitates the improvement of saline soils and the rice grower can also benefit by alternating his rice crop with other crops. Rice therefore has beneficially been grown in order to improve saline and alkaline soils which, after two or three years in rice, can successfully be used for growing other commercial crops to the benefit of the rice grower.

Origin of Cultivated Rice

The plant *Oryza* is one of the ancient crops whose cultivation goes back to the earliest days in the history of mankind (several millennia ago). From various sources, rice in China was known in the 5th millennium B.C., in Africa in 2000 B.C., and in Europe in the 8th century A.D. (on the Iberian Peninsula). Yet, the opinions as to the origin of cultivated rice are conflicting. It is customarily believed that the cultivation of rice began at the dawn of land cropping, and at about the same time, in various parts of South and Southeastern Asia.

Rice probably spread from Africa to all of the Mediterranean regions (Egypt, Spain, Italy) much later. The first crop of rice in Italy, for example, was established in 1468. It spread further from Italy and Turkey to Southeastern Europe (Bulgaria, Yugoslavia, Romania), and to other Balkan countries.

fertilizer application and other cultivation practices increased yields during this period.

In 1966, as part of the national land-reclamation drive, construction of irrigated-rice production systems began in all the areas where lands unsuitable for other field crops could be improved through reclamation practices and developed for rice production.

Rice crop has been established commercially in the Russian Federation, Uzbekistan and Kazakhstan. In 1975, about 85 percent of the national rice crop was grown in these three republics, with 57 percent of this figure coming from the Russian Federation. In 1980, the percentage from these republics grew to 92, 52 percent of which was contributed by the Russian Federation. Production of rice in this largest republic of the USSR is centered in certain areas of the Northern Caucasus, the Lower Volga, and the Far East (Primorye).

Krasnodar Territory,[1] one of the administrative divisions of the Russian Federation (Krasnodar is the major city) in the Northern Caucasus, is considered the country's "rice bowl". There production of rice is based on the use of engineered irrigation systems constructed along and in the estuary of the river Kuban on a former wasteland specifically developed for rice. By 1980, about 100 000 hectares of new land had been put to rice in this area. The irrigation requirement of the rice crop is fully met by the Kuban water and by a number of water reservoirs the largest of which (near Krasnodar) has been refilled recently to reach a storage capacity of 3.1 billion cu m.

On the whole, rice acreage in the Soviet Union increased from 95 300 hectares in 1960 to 666 000 hectares in 1980. In the Russian Federation alone it increased more than tenfold. Yield per hectare increased to 4.19 tons, and remains the country's average at present. The country's total rice crop in 1980 was 2.7 million tons.

Yield per hectare is a major characteristic of crop production. Satisfactory rice yields depend largely on the natural conditions of the area, economic considerations, the technology accessible to the grower, and proper management. .

In the past two decades, average yields per hectare increased by 2.23 tons, or 2.2 times. In the Far East, however, they increased by only 1.18 t/ha and remain the lowest (3-3.5 t/ha) in the republic. The explanation for this is that this rice-growing area has to choose to grow early-season rices which are always inferior in yield to the mid-, and late-season varieties of rice.

[1] Because of its major river, the Kuban, it is often referred to as the Kuban area.

Average yield in the country has fluctuated from year to year but showed a definite upward trend. This gradual increase in yield per hectare has been brought about by improved cultivation practices, such as better rotations, weed control, irrigation and fertilizer practices, better machinery and methods of controlling pests and diseases, and improved varieties. The achievements of the Kuban rice growers in this connection are convincing. By 1975 average yields per hectare in most rice farms had increased to 5 tons and have been maintained at about the same level through present times. Some rice growers have managed to gather as much as 10 t/ha of rough rice or more, although on limited acreage (from 8 to 30 ha). This, however, shows that the high potential of rice can be reached provided the requirements of the rice plant are fully met, and cultivation practices under efficient management are properly timed and executed.

1

ORYZA

Botanical Description

Rice is a grass (*Gramineae*) belonging to the genus *Oryza* Linn. of which two species are the most cultivated, *O. sativa* Linn. and *O. glaberrima* Steud, the latter being confined to small areas in West Africa. R. J. Roschevicz [1] was one of the first to report a comprehensive study of the genus in 1931 in which he concluded that there were 20 species of *Oryza.*

Oryza sativa is an annual species and includes a large number of botanical varieties and forms of which almost all are semiaquatic. For this matter it is customary to believe that the origins of the genus *Oryza* and of cultivated rice were rainfed lands, floodplains and river deltas.

The first Soviet classification of the species *Oryza sativa* was devised in 1934 by G. G. Gushchin [2]. According to him *Oryza sativa* falls into two subspecies: (1) *O. sativa communis* (grain length 4-7 mm, and more), and (2) *O. sativa brevis* (grain length about 4 mm). (*O. sativa brevis* is not grown in the Soviet Union). Gushchin divides *O. sativa communis* further into two branches.

(1) *O. sativa communis* var. *indica* is characterized by a long, narrow and slightly flattened (compressed laterally) grain with a length-width ratio of 3.0:1.0 to 3.5:1.0, and more. Normally, the *indica* varieties are awnless, or may have short and tender awns. Their floral glumes (the lemma and the palea) and leaves are slightly pubescent, having short and thin hairs. The leaf blade is broad and light-green. The blade of the uppermost leaf, or 'flag', is set at a small angle to the stem (culm), i.e. articulates and stands upright almost vertically.

(2) *O. sativa communis* var. *japonica* has a broad, thick and noticeably rounded grain or caryopsis with a length-width ratio of 1.4:1.0 to 2.9:1.0. The *japonica* rices vary greatly from awnless to awned forms, some of which possess long and coarse awns. The hairs on the floral glumes are thick and long. The leaf blade is narrow and bright green. The blade of the topmost leaf is set at a large angle to the culm and stands sideways, sometimes at right angles.

Both *indica* and *japonica* rices, which Gushchin called branches, have recently been recognized as the subspecies of *O. sativa*.

The *indica* branch includes 41, while the *japonica*, 104 forms and botanical varieties. The division of these subspecies into varieties is based on the following characters: (1) length of the outer glumes; (2) endosperm

starch-iodine-blue test; (3) curvature of the apex of the floral glumes; (4) presence or absence of awns; (5) color of fruit (grain); (6) coloration of the floral glumes and awns.

All rices grown in the Soviet Union belong to *O. sativa* var. *japonica.* The weed rices, i.e. red rices, are also forms of the *japonica* subspecies.

More than 350 varieties of *O. sativa* have presently been recorded although they do not cover the diversity of characters by which they can be said to differ one from another.

Morphological Characters

Rice *Oryza sativa* is a spring, herbaceous, semiaquatic plant. Its fibrous **root system** is composed of the *radicle* or *primary root* and the *adventitious roots.* At germination, the radicle develops from the base of the grain (the embryo). About the same time, the adventitious roots that arise from the tillering (lower) node are finely branched in the topsoil layer.

At tiller formation, the adventitious roots are fully developed and the primary root becomes unimportant because its role as the chief supplier of water and nutrients is by now negligible.

Small root hairs 0.7-1.0 mm long develop on both the radicle and the adventitious roots. The number of root hairs depends on the adopted practice of irrigation. Thus, the hairs are many if the rice sprouts from the wetted soil, the hairs are few if the crop sprouts through a layer of water.

At tiller initiation, the plant develops the secondary root system which differs in physical appearance and anatomy from the primordial root. An intensive root growth starts on the fifteenth day after emergence and continues till the appearance of the flowers. The root growth is maximum by the time of heading, though new roots keep growing till maturity, totalling in number to about 300. Generally, the number of roots depends on the soil and water temperature, irrigation patterns, tillage methods, rates of fertilizer applications, varietal characters, and other factors.

The plant roots function for a long time. At the best, they are capable, after harvest, of supplying the aftermath with all life essentials.

The size of the roots varies, but is usually small, ranging from 30 to 40 cm in length. With the submerged type of culture, the roots extend in the topsoil to 10-15 cm. Some of the roots, however, can penetrate to a depth of 35 cm. The roots of young plants extend largely to 8-10 cm. The stagewise distribution of roots depends on the physical properties of the soil and subsoil, in particular on the topsoil's physical condition obtained through cultivations, the amounts of available nitrogen, and the method

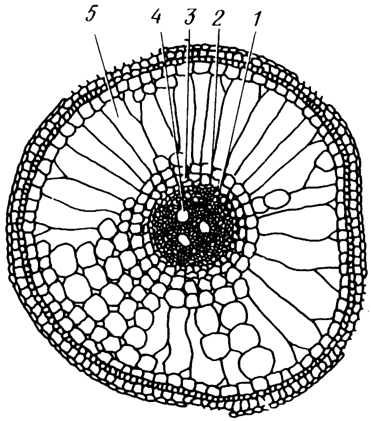


Fig. 1. A root of rice plant dissected to show the various parts
1 — spiral tubes, *2* — xylem fine vessels, *3* — phloem, *4* — xylem large vessels,
5 — aerenchyma (by P. S. Erygin)

of irrigation. The latter is essentially important for root development. Thus, standing in a depth of water, the plant develops roots which are more rigorous and physiologically active than in the rice grown with intermittent submergence.

As the rice plant grows, its roots structurally acquire features pertinent to the aquatic plants. This is due to the *aerenchyma*, a developed air-conducting tissue present in the roots, leaves and culms through which the above-ground parts of the plant supply air oxygen to the roots and, consequently, to the soil. In this way, the plant maintains essential oxygen concentrations after it has had 2-3 true (foliage) leaves, and grows comfortly under submergence.

The rice root is composed of various tissues (Fig. 1). Cross-sectionally, the root shows the *epidermis*, often with root hairs and underlain by the *mesoderm*, and the *endodermis*. The next is the *central cylinder* with a layer of thin-walled cells encircling it about the periphery. The above cells are intimately grown with the endodermis to form the so-called *pericycle*. Beside the pericycle, the central cylinder has the *xylem* (conducting tissue) and the *phloem* to join the xylem vessels together.

The presence in the roots of rice of the aerenchyma is ecological proof of the ability of rice to thrive when submerged, in other words, of its semiaquatic nature.

The **culm** (also **stem** or **stalk**) of the rice plant is a round straw divided

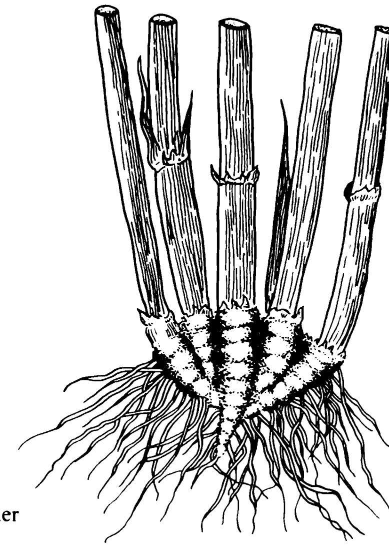


Fig. 2. Tillering node with primary tiller and four laterals

by solid nodes into sections, the *internodes.* The hollow upper internodes are longer, the lower solid internodes are shorter.

The culm completes development by the time of leaf-tube initiation. Its internodes, formerly grouped at the tillering node, elongate (Fig. 2). Each internode possesses the aerenchyma which communicates with a similar tissue in the leaves and roots.

The number of (inter)nodes is a varietal characteristic correlated with the length of the growing season. The internodes are fewer in the early-season rices than in the mid-season ones. The culm length is also a varietal character and ranges from 0.5 to 2.0 m. The rices grown in the Soviet Union range in height from 0.8 to 1.5 m. Dwarf (short-stem) varieties are 0.3-0.5 m high, while some "floating" rices cultivated in Southeast Asia may reach 5-6 m.

Normally, the rice culm does not tiller, but some produce a few tillers. Tillers develop only from the lower buds, chiefly at the second or third node. Sometimes, two tillers develop at one node.

Culms vary in diameter, always being thicker at the base and thinner at the top portion. This gives the plant a better mechanical strength and resistance to lodging. The uppermost longest internode, the peduncle, is the thinnest, and it bears the panicle. The thick culm may not necessarily

be strong. More often than not, strong and resilient in the beginning, a thick stem may by time of maturity become frail, and it readily breaks in the wind, usually at the second or third internode. In contrast, thin culms of many early varieties have proved more resilient and resistant to lodging.

The strength of rice stem depends mostly on the thickness of the straw walls. Short-stem rices with a stronger straw are more resistant to lodging than are tall or high-stem rices.

The *underground* or *tillering node* from which leaves develop is at the base of the culm.

The **leaf** of the rice plant is long and linear. It consists of the sheath at the base which surrounds the culm for some distance; the blade which is set at an angle to the culm; the ligule; and the auricules. It has no petiole.

The *sheath* is at the base of the leaf and quickly envelops the internode. It is open, naked and slightly rippen. Usually, the long and narrow *leaf blade* is veined, and feels rough and rigid. The blade of the mature foliage leaf reaches 35 cm in length and is 1.5-2 cm broad. The leaf size varies along with the stem height.

The *ligule* is usually a colorless glume which tends to split as it grows (Fig. 3). The sickle-shaped *auricules* envelop the culm to hold tight the sheath. On the convex side, each auricule is hairy.

The *coleoptile* is considered to be the first leaf to appear on the main axis of the plant, and is often called the primary tiller. It is an elongated, bladeless cap (calyptra) with a sheath only. The second leaf, which is rather a glume than a leaf, is green, but underdeveloped and has no blade either. Only the third leaf pushing through the caleoptile is a real green

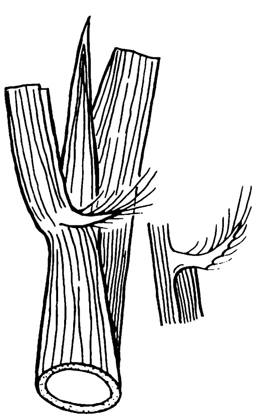


Fig. 3. Auricules and ligule

(foliage) leaf with a sheath and a blade. All other leaves are similar to the third differing only in size and the angle at which the blade is set with the sheath. The topmost leaf, or *flag-leaf* possesses a blade shorter and broader than the lower leaves. Its sheath first holds the panicle primordium and then the panicle axis. The number of leaves usually is equal to the number of stem nodes. Late varieties possess more leaves.

The leaves of the rice plant can be erect or slightly, moderately, or heavily drooping. Always, the leaves of the primary tiller droop less than do those on the laterals.

The rice inflorescence is a **panicle** developing on the culm uppermost internode called the *peduncle* or *pedicle* which base rests on the last culm node and its top, on the panicle lower node. The peduncle may be exerted, partly exerted, or rarely enclosed in the sheath of flag leaf. It is normally 1.3 to 1.8 mm thick, though in some varieties and forms where the culm lower internode is 8 mm in diameter and more, the peduncle may be 2.0-2.2 mm thick.

The panicle consists of the central axis (often rippen) divided into nodes. Several branches (1-5) arise alternately or somewhat in whorls at each node of the peduncle. The *rachilla* bears the spikelet, and each rachilla arises on the same side of the rachis. The panicle of most varieties is fairly dense, or loose (according to the number of spikelets per 1 cm length). There is much intervarietal variation since the panicle ranges from open to very compact, and from erect to drooping.

The size of panicle and the number of spikelets it bears vary depending on the biology of variety and conditions of growing. The panicle of Soviet rices ranges from 18 to 25 cm in length, and the number of spikelets, from 50 to 300.

The *one-flowered spikelet* consists of two *outer glumes* above which oppositely sit two *floral glumes*. The upper or superior one is called the *palea* and the lower or inferior, the *lemma*. The glumes can be smooth, keeled and rough. In some varieties the *apiculus* of the lemma is prolonged to form an *awn*. As a matter of interest, the awned forms of rice show more vigorous development than the awnless varieties. The outer glumes and awns can be straw-color, black or dark-purplish. The length of the spikelet is 2-15 mm (Fig. 4).

The **flower** consists of two floral *lodicules*, six *stamens*, an elongated *ovary* and two plumose *stigmas* on a *pistil*. The *anthers* borne on the stamen slender filaments are not longer than 3-4 mm; each anther contains up to 1 000 pollen grains.

Flowering or *anthesis* of rice starts immediately after the panicle emerges, fully or partly, from the sheath of the flag leaf. This usually oc-

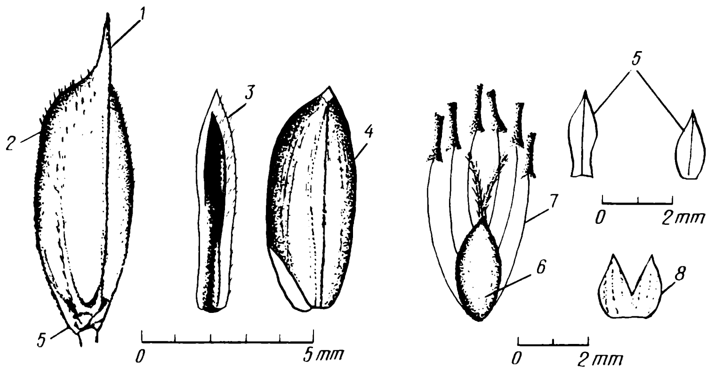


Fig. 4. A spikelet dissected to show the various parts
1 — awn, *2* — lemma, *3* — palea, *4* — caryopsis (grain), *5* — glumes, *6* — ovary, *7* — stamen, *8* — lodicule

curs in the forenoon. The greatest number of flowers open on the second or third day after the panicle has emerged.

Rice is a self-pollinator. The pollen is shed a little before or at the time the flower opens. *Cross-pollination* is rare, depending mostly on the weather and, to a smaller extent, on varietal character. Usually, cross-pollination does not exceed 1 percent.

The fertilized ovary develops into the fruit which is the *caryopsis* of various shape and color. The caryopsis is tightly enclosed by the lemma and palea (the "hull"), and not grown together with them.

The principal parts of the caryopsis are the covering tissues, i.e. the *pericarp* and *perispermium*; the layer of *aleurone cells* rich in proteins; the *endosperm*; and the *embryo*. The latter two are enveloped with the perispermium (Fig. 5).

The *endosperm* interior consists of starchy grains. Depending on the number and layout of the starchy grains, the endosperm of rices can be *mealy* or *vitreous*. In milling, the grain with the vitreous endosperm gives less brokens and meal than the caryopsis with the mealy endosperm. The cooking qualities of the mealy rice are poor as the grain softens rapidly and becomes "mushy" and glutenous. Rice grains with the vitreous endosperm swell even when overcooked and produce a cooked rice with each grain separate and non-sticky.

The *embryo* or *germ* lies in a slanting position at the base of the grain on one side of the endosperm. Accounting for 1.5-3.5 percent of the grain

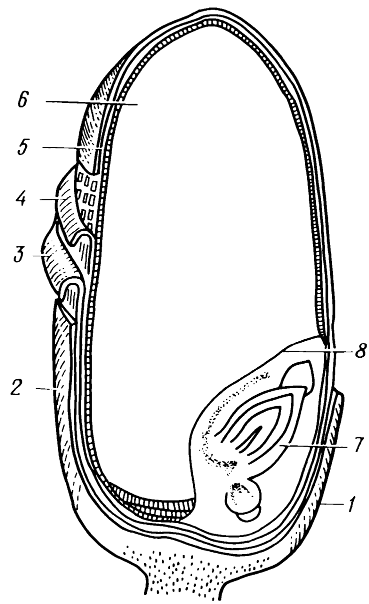


Fig. 5. Caryopsis dissected to show the various parts:

1, *2* — lemma and palea (hull), *3* — pericarp; *4* — perispermium, *5* — aleurone cell layer, *6* — endosperm, *7* — embryo or germ, *8* — cyme

mass, the embryo consists of the *budlet*, the *primordial radix*, and the *cyme*. Usually, the caryopsis bears one embryo which occupies one-third of its length. The embryo is rich in fats. With increased grain moisture, the fats are split by the enzyme lipase into free fatty acids. This renders the food rice rancid unless the embryo is removed in milling. Shed into a wet or submerged soil at harvest, the mature seeds rapidly germinate.

Development of the Plant

The life of the rice plant in the field may be divided into the following periods: germination, tillering, leaf-tube formation, heading (and flowering), and ripening. The transition from one growing stage to another is the effect of the metabolic changes occurring in the plant, which lead to the formation of new morphological features. The environmental requirements of rice at various phases of its vegetating life are therefore different.

At **germination**, the rice seed starts to absorb water until the grain moisture content (depending on the variety) is 23-28 percent. With the

flood irrigation which is widespread in the Soviet Union, the seeds start to germinate under anaerobic conditions, absorbing about 80 to 85 percent of water necessary for germination. The rest of the water that they absorb is required for the energy exchange occurring in the growing embryonic tissues.

The seed swells in an oxygen-free environment, i.e. pregermination is anaerobic. The seed requirement for oxygen arises at sprouting. The minimum temperature at which seed rice can germinate is from 10 to 16°C. The optimum temperatures are 22 to 25°C. Low temperatures are fatal and most seeds fail to germinate because of germ rottening. Rice varieties however vary in response to minimum temperatures. Of all the varieties grown in the Kuban River delta (the Northern Caucasus), Kuban 3 is the most cold-resistant variety. It gives good, uniform stands even when sown at early dates in April. The rice grain is able to germinate at 7-9 days of age (after ovary fertilization) right in the panicle when the seed is not dormant. Normal germination in the spring can however be obtained only with fully mature seed. The field germination rate is determined by the soil temperature which in turn depends on the irrigation water temperature and the air temperature. At an average temperature of 22-25°C, rice seedlings emerge within 5-7 days, at 16-20°C, within 10-12 days. If seeded early at a temperature between 12-14°C, it will take rice 14 to 16 days to emerge. As has been established, sprouting ceases at temperatures below 17°C.

The duration of flooding is very important for seedling establishment. With continuous submergence, the stands are thinner, while various types of short-term flooding (flush irrigation) aimed at wetting the soil to bring up the rice help obtain stands of a fairly good density. The period from germination to emergence ranges from 15 to 17 days and depends on the air temperature, soil moisture and, of course, on seed viability.

At **emergence**, early varieties develop 1-3 foliage leaves and mid-season varieties, 1-4 leaves, not counting the bladeless leaf. In this period, the root system grows intensely, and the buds of the future laterals start to form in the axil of the leaves. Air ducts appear in the roots to ensure satisfactory supplies of oxygen to the root system. With flush irrigation, rice during this period grows without the layer of water. It is built up in the field later at full emergence.

Tillering starts with the third or fourth foliage leaf appearing on the plant and ends when the plant has 8-9 leaves. The minimum temperature for tiller initiation is 14°C. The rate of tillering varies with varieties, but it depends still more on environmental conditions, nutrition, in particular. Topdressings with fertilizers at emergence facilitate the production of the

lateral tillers. A second dressing at mid-tillering results in large panicles produced by the secondary tillers. For this matter, panicles on the tillers that have developed from the axils of the second, third, fourth and even the fifth leaf are as productive as the panicles produced by the main tiller. The rate of tillering depends on the depth of water, day length, and plant density per unit area.

The formation of tillers is accomplished within 25-30 days. Being the longest phase in the organogenesis, this stage is fully responsible for the formation of a productive panicle and determines the length of the growing period of the variety. It will be noted that in early varieties, the period of intense tillering (the formation of 5-6 leaves) coincides with the time when the apical growing point (the vegetative apex) develops into the panicle primordium, i.e. it differentiates. In mid-season varieties, e.g., Krasnodarsky 424, differentiation of the apex starts with 8-9 leaves on the plant when tillering subsides and the plant enters the next phase of its life.

Leaf-tube initiation begins when the rice plant has developed 8 to 9 leaves. During this time, the culm upper internodes, topmost leaves and the panicle primordium grow intensely. The panicle forms from the apical growing point, which is a hemispherical protuberance covered with rudimentary leaves. At the initial stages of growing, the vegetative apex forms the vegetative organs (leaves). Later on, the growing point becomes more complex with differentiation, which results in various organs of the panicle. The panicle primordium progresses through several stages. Hemispherical protrusions with nodes are observed which represent the branches of the panicle. Rudiments of the spikelet are perceptible as are the outer glumes. This is followed by the separation of the lemma and the palea and the formation of the pistil and ovary. The initiation of the flower organs (stamens, pistil and ovary) is completed by the time of anthesis. The flower formation proceeds from the tip of the panicle and continues progressively down to the base, at each branch of the panicle.

The number of spikelets in the panicle varies with the variety and environmental conditions. Even short-lived changes in the environment at differentiation of the growing point may influence, both ways, the number of spikelets setting in the future panicle. For example, high temperatures at the underground node accelerate the setting of spikelets and lead to a rapidly produced panicle with only a few kernels. Relatively low temperatures at panicle formation have a beneficial effect resulting in a panicle with a fairly good set of spikelets. The larger the size of the growing apex prior to differentiation, the more branches and spikelets are set in it. Field practices should therefore be aimed at increasing the size of the growing point. Of these the most important are timely nitrogen ap-

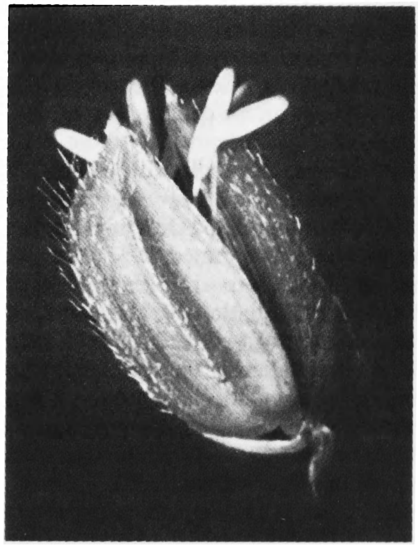


Fig. 6. Anthesis in rice. Opening of the lemma and palea

plications (presowing and postemergence topdressings), cooling down the water through increasing its depth or renewing it by continuous inflow and outflow, etc.

Anthesis. By the time the panicle is formed, the uppermost culm internode has markedly elongated to help the panicle emerge (boot) from the sheath. A new stage in plant development, the *anthesis* (*blooming* or flowering) begins. In rices, the heading or tasseling coincides with the blooming. Flowering is said to be open when pollination and fertilization occur with the lemma and palea opened (Fig. 6). It is called closed when they do not open. The anthesis in rices sown in this country is usually open, and rarely closed where air temperatures and humidity are unfavorable.

Air temperature and humidity affect flowering and fertilization of rice. At relatively high temperatures rice blooms from 9 a.m. to 2-3 p.m. The optimum air temperature at this time is 27-28°C; the minimum, 15-20°C, and the maximum, 50°. Relative humidity between 70 and 80 percent is most beneficial. No pollen is shed at humidity below 40 percent as this affects the stigma. Cloudiness, wind, rain, and a sharp drop of temperature to 12-13°C may delay or even stop flowering and fertilization.

The anthesis of the primary panicle occurs over a period of 5 to 7 days resulting in the fertilization of the ovary from which the embryo or germ is produced. This is followed by the filling of the endosperm to grain maturity. By the age of 10-12 days, the embryo consists of all the organs that develop to produce the rice plant. But it reaches its maximum size and mass within 27 days after fertilization.

Ripening involves three stages:

In the *milk grain stage*, the caryopsis reaches the maximum length and width (dorsoventral diameter) but the content of the grain is a white liquid that can be squeezed out. The period from pollination to this stage constitutes 11-12 days. The caryopsis interior is 70 percent water.

In the *dough grain stage* that constitutes 20 days, the milky portion of the grain turns first into a soft, and later a hard dough. Containing up to 35 percent water, the caryopsis can be readily cut with a finger-nail. This simple test is a rule of thumb with the practical farmer.

In the *mature grain stage*, grain color in the panicles begins to change from green to yellow. The individual grain is mature, fully developed, and is hard and free from green tint.

The time range from the dough grain stage to mature grain stage is from 5 to 7 days. Ripening duration (30-40 days, 45 and even more for late varieties) depends on rice biology, air and soil temperatures. The caryopsis is said to be fully matured when it does resist the finger-nail test and produces dry grits when crushed.

Environmental and Nutritional Requirements

Rice is a thermophilic plant and responds well to a range of diurnal temperature changes. Minor deviations from the optimum temperature range during any of the vegetative phases prolong or shorten the length of growing period of the rice plant. The practice of rice cultivation in the Northern Hemisphere indicates that early rices grow well and never fail to mature in the rice-growing areas where the average diurnal temperature during the growing season of rice is not lower than 17.5-18°C.

High temperatures and day length of about 12 hours are essential for the formation of productive organs of the plant irrespective of its variety. Low temperatures markedly retard plant growth and development. Late frosts (−0.5°C) are injurious, and the temperature −1°C is fatal to rice. By their growing period in the Kuban delta lands, rice varieties from the

Germ Bank of world plants maintained at the VIR (Institute of Plant Industry, Leningrad, the USSR) [3] can be grouped as follows (Table 1).

Table 1. Maturity Groups of Rices [3]
(After Sokolova I. I., the USSR Rice Research Institute, Krasnodar)

Group	From seeding to heading, days	Maturity or growing period, days	Degree-days*, °C
Very early	45-50	90-100	2000-2200
Early	51-55	101-110	2200-2300
Early mid-season	56-65	111-120	2300-2500
Mid-season	66-75	121-125	2500-2600
Late mid-season or late	76-100	126-140	2600-2700
Very late	fail to head	fail to mature	more than 2700

* Sum of above-critical temperatures (+ 15 °C) for the growing season.

The rice plant adapts readily to a diversity of environments. For this reason rice has spread in the world so widely that it thrives both in the tropical and temperate zones. The northernmost areas of rice cultivation border on the 2000-2200°C isoline for the May-September season. Spreading it further north is possible through the use of early and satisfactory high-yielding varieties.

In this country, rice is grown in six areas distributed within two climatic zones: the temperate and the subtropical.

Rice will grow, under appropriate temperature regimes, wherever there is enough water to sustain a crop. For this reason, usually meadow, bog-podzolic, chernosem (blacksoil), chestnut and like types of soil are considered most desirable because they prevent excessive seepage losses. Rice can also be grown in saline and alkaline soils (solonchak and solonetz). But it is to be remembered that concentrations in soil of sodium chloride higher than 0.2 percent, and of sodium carbonate higher than 0.1 percent may seriously reduce germination and stand establishment. Excessive salts can, however, be removed in a short time by flushing the soils. To achieve this, repeated floods are established on the riceland which is drained a

week or two after. Because rice can be grown in overwet soils, it is often used as a reclamation crop in many rice producing countries. For this purpose, rice has been grown in the European USSR in very saline soils of the Terek delta, the Kuma-Manych Basin, and the Cis-Caspian Lowland. The quantities of flushing water were varied from 5 000 to 25 000 cu m per hectare depending on the degree and character of salinity.

Rice grows poorly in the forest grey soils. Heavy soils in delta areas that prevent heavy seepage losses are considered preferable for the submerged type of rice culture.

A soil with pH = 7 is satisfactory for the growth of rice. But soils with pH = 5.6-6.5 are the most desirable.

Rice is very sensitive to the lack of nutrients. During the growing season it absorbs large amounts of nutrient elements of which nitrogen, phosphorus and potassium are most essential. Because of this, rice is said to be the soil "miner" or "impoverisher". Shortage of essential nutrients, especially nitrogen, seriously impairs the grain yield. Nitrogen deficiency brings about typical foliar symptoms (yellowing), reduces photosynthesis, tillering capacity, and the size of the panicle, which often has poorly set grains. Rice needs nitrogen throughout its vegetative life. The plant requirement for nitrogen per unit of dry matter produced is highest at emergence. This implies that high levels of production are possible only with split application of nitrogen fertilizer.

Large amounts of nitrogen in the soil cause excessive (nonproductive) tillering and undesirable vegetative growth. The excess nitrogen prolongs the growing period and increases the percentage of floret sterility. Large quantities of nitrogen decrease the weight of 1 000 grains, increase rice susceptibility to *Pyriculariosis* thus impairing the yield, and lowering profits from rice production.

Rice benefits much from phosphorus. A deficiency of phosphorus in the soil causes metabolic disturbances in the plant resulting in a narrower leaf blade and poorly developed root system. Phosphorus deficiency delays tillering and results in a small-sized panicle. Lack of phosphorus in the very beginning of plant growth is hazardous because it cannot be corrected by the application of this nutrient during the subsequent stages of rice development. Presowing applications of phosphorus fertilizer and topdressings are therefore most desirable.

Unlike other agricultural crops, rice assimilates equally well both the water-soluble phosphates and the almost insoluble acid phosphates of calcium and iron.

Of all the soil nutrients, potassium is the most usable element. Because potassium participates in the transformation of carbohydrates, its defi-

ciency in the soil reduces storages of dry matter in the plant. Potassium requirement of rice is highest from the end of tillering to blooming. The availability of this nutrient at this time is therefore beneficial to rice. Generally, the response of rice to potassium fertilizers added to the soil is not as marked as for nitrogen and phosphorus because the requirement of the plant for this element is satisfactorily met by a fairly good amount of potassium in rice soils and floodwater. A deficiency of potassium in some soils delays growth and reduces productive tillering.

Beside the essential nutrients, such as nitrogen, phosphorus and potassium, the micronutrients such as sulfur, iron, calcium, copper, zinc, molybdenum, manganese, and others are important for the development of the plant. Almost all of these elements are the constituents of the enzymes that govern the biochemical processes during plant life. The presowing application of micronutrients to the soil, or use of these for seed dressing increases the productivity of rice soils, and improves tolerance of the rice plant to adverse environments.

2

IRRIGATED-RICE PRODUCTION SYSTEM

Rice in the Soviet Union is an irrigated, lowland culture grown in the lands developed as water-engineering systems to which irrigation water is led by gravity flow or pumped. Such or similar type systems make possible the mechanized cultivation of rice with assured maximum grain yields.

Surface flood irrigation is used for all rice grown in such engineered rice systems. The soil is submerged most or all of the time from seeding or shortly after, until the grain is nearly ripe. The layer of water is distributed as uniformly as possible because its absence or deep submergence are equally undesirable for rice.

By gravity flow, the water is conveyed from a stream or river in canals (where necessary, the stream is dammed). The grade of the canal bed is made smaller than the natural river-bed gradient. The water is gradually delivered to the highest point in the field which "commands" the area to be irrigated.

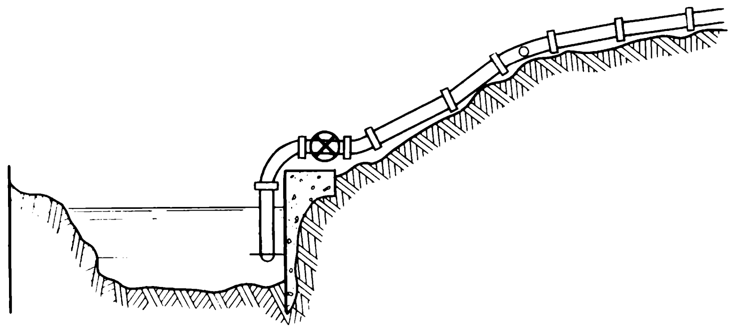


Fig. 7. Pumping water for irrigation

Irrigation water is delivered by pumps if the water surface in the stream or other source of irrigation water is much below the elevation of the riceland to be irrigated. Pumping plants have thus to be installed to supply water to the rice fields although this certainly increases the operational cost of the irrigation system (Fig. 7).

The irrigated-rice system, mostly of the *open-ditch* type, is a complex water development. Its primary aim is to ensure a dependable supply of good-quality irrigation water for successful rice cultivation, hold the water in the field most or all of the growing period, and rapidly withdraw the water from the field, as may be required.

The engineered system for rice cultivation (Fig. 8) consists of the water conveyance network, the rice field, the importation or drainage network, water control structures and protective ditches.

The *water conveyance network* includes intake (diversion) structures (where water is to be led by gravity), main and distributing canals or laterals with various dividers, regulating structures and mechanical fixtures; and field supply ditches.

The *diversion* or *intake structures* are dams or weirs built at the headrace work (see Fig. 8) to raise the water level and lead the water in canals by gravity. The headworks serve as gates and regulators to control the flow of water to the rice production system. The headwork includes a number of gates which are opened or shut as required to adjust the supply of the irrigation water to the rice fields.

The *main canals* are ditches conveying most or all the water necessary for rice cultivation. The water is distributed through the dividing and multiple offtake structures placed at the highest points through which the canal passes. The main canal may branch off into *laterals*.

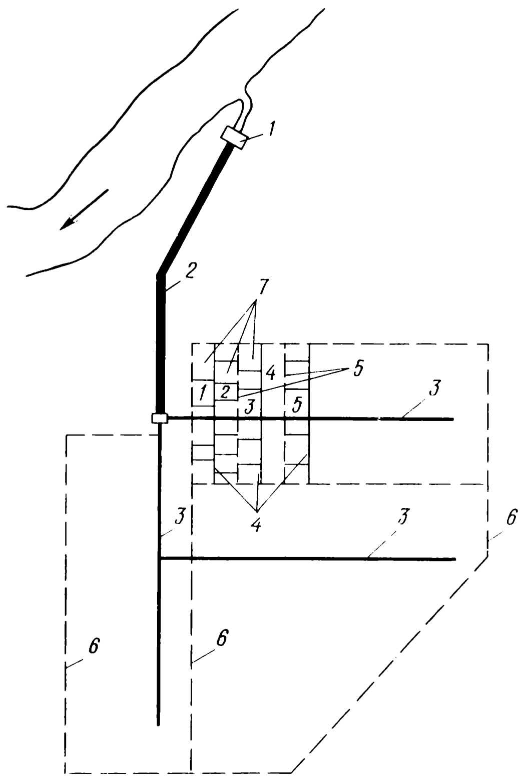


Fig. 8. A schematic of irrigated-rice system

1 — headwork, *2* — main canal, *3* — distributor, *4* — check supply ditch, *5* — check waste ditch, *6* — drainage header, *7* — checks and rice paddies

Distributors or *primary canals* direct water from the main canal or one of its laterals. One primary canal serves one or several farms. The distributors may further branch into *secondary canals* or *distributaries* which, in their turn, split water into distributary *minors* or *tertiary canals* that may divide water still further into *subminors*, etc.

In Soviet irrigated-rice systems, riceland is developed for the *level-basin method* of flood irrigation. The method involves applying water to a level-ground area often rectangular in shape surrounded by a check barrier, such as a *levee* or *dike*. The field area enclosed by a levee is known as

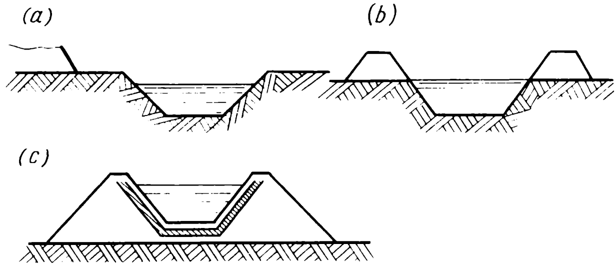


Fig. 9. Sectional view of canals or ditches
(*a*) in cut, (*b*) in cut and fill, (*c*) in fill

the *check-basin*, or *rice paddy*. For convenience, we shall further use the simple term check alternately with rice paddy.

The *field supply ditch* from which the irrigation water passes directly into the check constitutes the final unit of the irrigated-riceland development called the *rice system*. The field supply ditch may be of the one-, or two-command type to irrigate checks lying on any one side, in the first instance, and on both sides, in the second. The bilateral scheme of water supply is desirable for use in riceland where soils are fairly good for rice cultivation (nonsalty flatlands).

The two-command field ditch is usually carried in fill along the rice field and terminates with a turnout or outlet. The one-command field ditch is constructed preferably in fill than in cut and is carried only to the nearest corner of the last check-basin (Fig. 9). Whenever necessary, this last check can serve as the drainage basin. The checks on either side of the field supply ditch are usually grouped into field blocks, which we shall further call *large checks* because in some cases cross levees within such a check may be missing and the whole area within will thus constitute a continuous rice paddy. The large check may vary in size from 15 to 50 ha, depending to a great extent on the lay of land (topography). Usually it is made up to be 150-200 m in width allowing for easy and fast drainage as may be required.

A rectangular pattern for large checks is common, and is considered the most suitable shape for rice paddies. In different rice-producing areas, the size of check may vary from 0.1 to 0.6 ha. An average size of check in a rice system engineered for mechanical cultivation ranges from 2.5 to 3.5 ha. The check's longest dimension is no less than 150-200 m to allow easy manoeuvering and efficient operating of the rice-farming machinery.

Large rectangular checks (known in this country as the *Krasnodar-type* checks) have become common for modern irrigated-riceland

developments. Checks of this type consist of rectangular subfields or paddies with their longer dimension along the natural slope. Such a position helps minimize the slope gradient across the check to the extent that the longitudinal levees become unnecessary. The checks, bordered by the water supply ditch on the one side, and the waste ditch on the other, are thus enclosed on both sides. The water passes into each successively lower paddy from the field ditch, and is channelled into the waste ditch. In this way, each subfield can be separately flooded as a unit (Fig. 10).

Where the lay of land is unfavorable, checks are allowed to have longitudinal ridges so that the paddies are benched and the irrigation water first floods the half-paddy bordering on the supply ditch; it then overflows the ridge to flood the other half. The check is drained in the reverse manner. The water is first drawn from the half-paddy bordering on the waste ditch and then from the other half. Because both halves are interdependent, all field operations on the check must be performed simultaneously.

Rice is grown in large checks or/and their subunits, which are rice paddies. These have to be identical in all aspects to provide similar conditions for successful rice cultivation. Keeping water at a desired depth, determined by the phase of plant development, is particularly important. To achieve this, the check surface must be as level as possible to within ± 5 cm. In the fields inadequately graded, the raised patches and hammocks are improperly flooded. This encourages weed growth that suppresses the rice plants and impairs the grain yield. The flood water is deep at sloughs and hollows. At emergence, many rice seedlings die if unable to come through the thick layer of floodwater. This reduces stand establishment and, consequently, the grain yield.

In developing land for rice, achieving a true contour in checks is made possible through land-forming and subsequent leveling or planing. In grading, high spots in the soil are "planed" off and surplus earth is

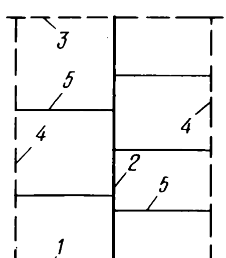


Fig. 10. A large rectangular check (the Krasnodar-type)

1 — distributor, *2* — check supply ditch, *3* — drainage header, *4* — check waste ditch, *5* — levee or dike

deposited in low places. At fills, the soil tends to settle over time, or because of wetting and compaction. Soil subsidence sometimes is 1/4 to 1/6 of the fill height. To avoid hollows at low spots which have to be filled, allowance is made for soil settlement. At cuts, where the subsoil is brought to the surface, subsequent tillage may cause swelling of the soil. Because of this, high spots and ridges must be cut a little deeper (by 2-3 cm) than specified by design.

When developing an area for rice checks, the lay of land may necessitate that much earth be cut. This requires that the richer topsoil be removed that will seriously affect grain yields for a number of years. A solution to the problem is the method used in soil reclamation whereby the topsoil is moved and stockpiled first. The stripped land is then graded and filled over again with the previously removed topsoil, after the low spots have been filled with the underlying soil material.

Initially, the land to be leveled is first surveyed, and cuts and fills calculated. The admissible values of cut and the choice of the land grading method depend on the depth of the topsoil. Where the fertile top layer is deep enough, cuts may reach 25-30 cm. But in shallow soils where the organic matter lies within a layer of 15-20 cm only, the practice is to distribute the topsoil evenly over the graded area.

The field checks are enclosed by an earth bank frequently called the *levee, dike* or *bund.* The levees are made with a sufficient freeboard to be high enough to hold depths of water up to 25-30 cm. Some levees are made to be passed over by tractors and implements, others are made impassible. In the former case, the levees have a slope ratio of 4:1 (the base of levee is 4 times its height) and are 310 cm wide at the base. Practically, they are wider, and a considerable cropping area is thus wasteland. In checks larger than 2 ha, the levees are made with a slope ratio of 1:1.5, impassible, but strong enough to resist washing.

Frequently, the levee around a check is built not to be passed over by machinery but with a flatter pass, about 10 m wide, provided at a check corner.

In a rice field with check-basins between levees set at 100 m, from 3 to 5 percent of the riceland is devoted to levees, whereas with checks between levees set at 200 m the wastage of land is much less than 3 percent. Certainly it is desirable that the area of land devoted to levees be reduced to a minimum. Seasonal straightening and reshaping the levees is a common practice used to minimize land wastage.

Improvement in the large check made by the USSR Rice Research Institute has brought forth the so-called check-paddy which is a check with a wide front for water advance and water withdrawal (Fig. 11). In fact,

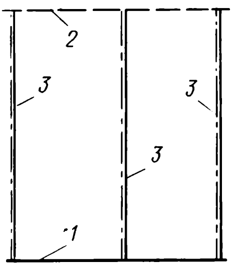


Fig. 11. Check with a wide front of water advance and water withdrawal

1 — distributor, *2* — drainage header, *3* — supply (waste) ditch

the check-paddy is a large flat check-basin bordered on one of its longer sides by a water supply ditch carried in cut with its lower bank crest made level with the check ground surface. Because of this, the supply ditch is also used as a waste ditch to drain water from the check area when required. From a distributary, the water passes into the field-supply ditch through a sluice-regulator (box) at the head of ditch. As soon as the ditch is full, the irrigation water overflows the crest and advances on the check-paddy over its entire length. The check is drained through an outlet provided for this purpose at the tail of the field-supply ditch.

Depending on the topography of land, the check-paddy may vary in size from 12 to 25 ha. With the turnouts of properly selected capacities, the check-paddy can be flooded and drained more rapidly than other types of checks discussed previously. Other advantages of the large check-paddy are:

higher coefficient of land use;

fewer water structures;

lower cost of developing one hectare of riceland;

increased efficiency of tractors and combines;

enhanced labor productivity of the irrigator.

The use of the wide-front advance check-paddy for an irrigated-rice system is determined largely by the land contour. Constructing such check-paddies in a riceland which is rolling or sloping is unadvisable because this will involve costly grading operations, and the land thus disturbed will remain low-productive for many years after.

A recent development in mechanized rice production has been the *Kuban rice system*[1] based entirely on the use of standardized construction articles for all of its design elements. Standardization greatly improves the efficiency of the planning, design, construction, and the practical application of such engineered rice systems to new lands developed for rice.

[1] Developed by the Kuban Institute of Water Projects, Krasnodar.

The Kuban rice system employs check-basins or paddies which are 6 ha (200 × 300 m) in area, and field supply and waste ditches of the two-command type. The check consisting of two paddies is 12 ha in size with 12 checks making up a 144 ha rotational rice field.

The advantages of the Kuban scheme over the known rice systems used by rice growers can be summarized as follows:

(1) The system helps save about 5.5 percent of irrigation water which roughly comes to 1 000 cu m per hectare per year.

(2) It increases by 3.5 percent the coefficient of land use, consequently raising the increment of the total rice output from the entire system by about the same percentage.

(3) It requires a 5 percent less capital input.

The Kuban system of rice production being more convenient in use opens possibilities for subsequent automation of water management. In developing land for rice, this system ensures the effective planning, construction and use of the irrigated riceland. It complements well the local landscapes and improves the drainage of the irrigated lands. It also permits the rice growers to take advantage of various types of irrigating machines to water other crops rotated with rice. The open-ditch irrigation under this system can be easily converted or replaced with low-pressure pipeline irrigation to transport water for rice and the accompanying rotational crops.

Another type of large check for rice is widespread in the Monsoon rice-growing areas of Primorye (the USSR Far East). This check differs in that it has neither a border, nor longitudinal levee on its lower (downstream) side. It has one field supply ditch which also drains the check area and the plowing layer of soil (Fig. 12). As the supply ditch carried in cut runs full, the irrigation water overflows its lower bank and advances on the check surface with a front that is the entire length of check. The earth from the supply-ditch cut is used to build access road embankments. The levees

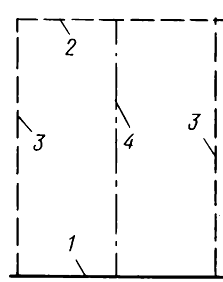


Fig. 12. The type of check used in the Far East

1 — distributor, *2* — drainage header, *3* — waste ditch, *4* — two-command supply (waste) ditch

across the field are constructed so that they are easily passed over by the farming machines and implements. The check is usually 100-120 m wide, 600-1000 m long, i.e. 10-12 ha in area.

Pipeline irrigation is much superior to the open-ditch method in that it prevents heavy seepage and filtration losses. A system for rice production with pipeline irrigation has been engineered for the Danube delta lands in the Ukraine.

The *drainage* or *importation network* is designed to carry away or divert the water drained from checks and rice paddies (off-season, it collects and takes away the surface runoff and ground waters). It includes (1) waste ditches to drain checks, which are not less than 0.7 m deep and carried along the check on the side opposite the supply ditch; (2) waste-water headers which collect the water from check waste ditches; and (3) waste-water mains that catch all wastage to divert it from the system layout to specialized waste-disposal structures or natural drainage ways. In that respect the whole network is ditches of various size and duty.

Good surface drainage is as necessary for successful rice culture as a dependable supply of good-quality irrigation water. Ground water drainage in rice production systems laid in saline soils and lands with a high water table is mandatory. The major purpose of the drainage and waste ditches in a rice system is to prevent inundation and water logging of rice paddies, and to lower the water table to safe levels.

The rice system's *protective network* consists of ditches of various size and duty intended to intercept the infiltration and seepage waters. Another major purpose is to prevent damage to rice fields and other rotational crops from storm and cloudburst runoff.

The *water control structures* provide precise regulation of the flow rate of water from the delivery canals to field supply ditches and passage of controlled discharges from supply ditches to each check or paddy and from the rice field to the waste water disposal. The irrigated-rice systems discussed earlier employ permanent water-control structures such as gates, weirs or dams, and turnouts or outlets. They all may be different in design or capacity but of equal importance for an effective rice production. Some of these structures serve the purpose of diverting water or creating backwater, while others pass controlled discharges, regulate the water level in canals and maintain the desired depth of water in the rice paddies.

In most cases the irrigation water is conveyed from rivers or other sources of water in canals from which it is diverted into field-supply ditches, and, finally, into field checks and rice paddies. The successive inflows of water are controlled by *gates* which are opened or shut to adjust the rate of flow, and are installed at the head of canal. Gates also control

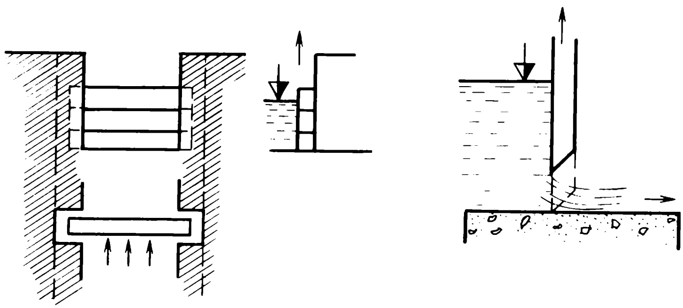


Fig. 13. Types of gate
(*a*) stop-planks, (*b*) lift gate

discharges from the distributaries to field ditches. Such gates, also called boxes, are simple structures consisting of a pipe and a reinforced concrete bulkhead. Such boxes placed at the tail of a check waste ditch can pass out the wastage to a header when opened, and cut the header off to raise the water level in a supply-waste ditch by creating backwater, when shut.

Gated weirs or *walls* are structures on canals which are intended to provide a closure of the canal section and raise the water level in the canal by creating afflux. These structures are usually reinforced concrete slabs with a rectangular or circular opening of various sizes provided with wooden or metal shutters (panels). In the vertical fixed portion of the structure, slots are sometimes provided so that short stop-planks, called flashboards, 5 to 10 cm wide can be inserted or removed as desired to raise or lower the water level at the diversion point into the field (Fig. 13). Such gated weirs are used only where the riceland has considerable slopes, so backwater is required to raise the level in the field ditch to and over the surface of the highest rice paddy. The difference in water level between the field ditch and the check surface should exceed 5 cm; the 25-30 cm depth of floodwater necessary to suppress barnyard grass at a specific time during the growing period.

Irrigation water within a rice field is controlled with levee *turnouts* or *outlets.* The levee turnouts are the most numerous structures in a rice production system. Of many known such structures, the two simplest types, the "monk" and the "flapper" are in common use. The first is widespread in the Kuban, Uzbekistan and the far-eastern rice producing areas, and the last is famous with the Don and Ukrainian rice growers.

The "monk" turnout consists of a pipe and an inlet bulkhead which is a rectangular reinforced concrete box. Its headwater side is either open or is a wall having an opening provided with wooden flashboards or planks that can be inserted in or removed from fixed slots. Its tailwater side or wall has a bottom opening to receive an asbestos-cement 200 mm dia. pipe (or pipes) with the top placed in level with the check ground surface.

The "flapper" is an asbestos-cement pipe placed across the body of levee, also with its top in level with the check surface. A wooden shutter (flap) is hinged on either end of the pipe, and operated manually. Simple and easy to operate, these control structures are not free of disadvantages, however.

The "monk" is frequently inconvenient for mechanical reshaping of levees and road banks, and for cleaning ditches. Silting of the inlet and outlet pits, loss of flashboards or stop-planks are its other demerits. With the "flapper" type of turnout, irrigation water may leak through the shutter if the closure is not tight enough, causing heavy wastage by leakage. Besides, the turnout is unadjustable to control streams of water during mechanical cleaning of ditches, and is therefore often liable to mechanical damage.

The **access** or **service roads** constructed around rice fields are important for successful rice production. Access roads are necessary to deliver seed rice, fertilizers, machines and implements, construction materials, etc. Some access roads are made crowned and sufficiently wide to accommodate truck traffic and heavy rice farming machines, such as combine harvesters. Each check should have access to a service road. Where traffic is heavy, access roads are constructed with a coat of gravel.

The **duty of water** or **water requirement** is the amount of water (in cu m) supplied to irrigate 1 ha of rice field during the growing period. (A 10 cm layer of water spread over 1 ha constitutes 1 000 cu m.)

After the rice field is flooded, a considerable amount of water is required to maintain an optimum depth. More water is periodically added to make up for losses due to transpiration by plants, evaporation from the water surface, deep percolation and spillage. Some losses, such as evaporation and transpiration, called *evapotranspiration*, are unavoidable, others can be controlled. The losses will vary depending on the amount of plant growth, temperature, soil type, solar radiation, relative humidity, and rate of water inflow into the field.

Evaporation from the water surface depends on air temperature and wind force. It starts immediately after the check is flooded and it stops after it is drained. Its rate changes with the growing period, slowing down, even at high temperatures, as vegetative growth builds up reducing

the vegetation-free surface. Evaporation increases with the temperature and wind force where stands are uniformly established.

Transpiration starts at emergence and increases with the growth of plants. Elevated temperatures, heavy fertilization, and strong winds increase transpiration. The denser the stand and the more rigorous the growth, the higher the water losses by transpiration.

Before the first flood is applied, the soil is relatively dry with many air voids between its clods and particles. To establish the desired depth of water on a check surface, the soil needs to be saturated so that the air voids are filled with water. The process of soil saturation is called the *priming of soil.* At the first flood, the soil rapidly absorbs water. Absorption gradually stabilizes as the water fills up the soil air voids and cavities. The only water losses during this time are deep percolation, downward infiltration and leakage from the checks. Depending on soil type, bulk density and moisture content, the priming of one hectare of soil requires from 1 500 to 3 000 cu m of irrigation water.

Submerging the land in a rice system causes the water table to rise, which is not always desirable. High water tables are hazardous in saline tracks of land and fields sown to rotational crops other than rice. To prevent the injurious action of the ground waters on crops, protective ditches must always be kept operable.

Application of the first flood, or flushing, should be rapid to economize on water and avoid deep percolation losses which are likely to occur at low rates of submergence. Rapid flooding is important to bring up rice quickly and obtain a uniform stand. Because the seed germinates only when the soil is fairly moist, a slow advance of water may delay emergence. With flush irrigation it is very important not to overirrigate to avoid wastage and fertilizer losses, and keep nutrients within the root zone. Otherwise excess water inevitably removed will carry away all the nutrients dissolved in it. Overirrigation frequently deteriorates the physical conditions of the soil in successively lower checks, and overfills the waste ditches.

Downward percolation (infiltration) will vary depending on the soil type, in particular the underlying rock formations. Most desirable are soils underlain with clays where deep percolation losses are minimum, irrigation requirements less, and water temperature remains beneficial for rice.

A second flood is applied about as soon as the rice plant is old enough to withstand submergence. Unless the field must be drained for pest or disease control, the flood is continuously maintained. Frequently, the flood water has to be lowered to specific depths without drawing it down completely from the field. Special reasons for a drawdown include top-

dressing, stand establishment, tiller formation and weed control. It is advisable not to remove the water through drainage but stop for some days its supply to the field. The depth of water will be reduced due to evapotranspiration or will recede due to deep seepage.

For a successful rice culture, floodwater should be regularly replenished to avoid stagnation, particularly on saline soils and small-sized rice paddies. This can be achieved by a continuous inflow and outflow. It has been established through tests and practical observations that a flow of water through the field aids in keeping the body of water cool and in preventing the growth of injurious plants that thrive in the stagnant water. In this way the crop may be nearly doubled. In keeping the water flowing through the field it is very important to ensure precise control over inflow and outflow to minimize drainage, avoid overirrigation and wastage, and save the downstream interests. It is to be remembered that overirrigation usually impairs, not improves yield.

Water balance. The water and irrigation requirements of rice paddies necessary for the normal development of these plants throughout the growing period vary. The irrigation intensity (in litres per second per hectare) at various phases of the rice life is called the *water module*. The water module or water consumption chart shows the distribution of irrigation water over the growing period. The peak water demand, i.e. the highest water module, is observed at the first flood; it is assumed for the calculation of the capacities of canals and water control structures.

Water amounts supplied to the large check or the entire rice production system and lost (used) make up the water balance. An accurate account of its data provides a judgement of the efficiency of water application (the ratio of water required for irrigation and the amount of water applied). The amount of water required to obtain a yield of 5-6 t/ha constitutes about 13 000-19 000 cu m.

Sometimes, to improve the water balance of a rice system, the irrigation water can be used in the fields a second time (recirculated) if it contains no more than 1.5 g/l of salts.

The water rotation chart in an irrigated-rice production system serves as a practical guide for proper water management. It specifies the time (dates) of planting and water applications in turn for each farm and field subdivision on the basis of the known cropped areas and their irrigation requirements. A good aid in managing labor, such a plan of water rotation is drawn so that the irrigation water is suitably distributed from the headrace of the system and each distribution point. This helps avoid overfilling and damage to the water conveyance and waste networks from excessive water.

Because the water requirement of rice varies with the age of plant, the items of water balance for various vegetative phases may not be the same. After the first flood is applied to bring up the rice, water balance consists of the water supplied and lost by evaporation and soil saturation. Transpiration and deep percolation losses, and wastage will add up later in the growing period.

Post-Construction and Seasonal Uses

In developing lands for rice, some irrigation and drainage structures are completed earlier than others and can be put to agricultural use immediately, but not until they are properly checked to see if the grading has been precise and large checks are as level as desired, cross-section of the canals and elevation of the irrigation and drainage structures are consistent with the designed, canals have no reverse slopes, and all the temporary closures are removed. If no such faults are found, the canals and ditches can be primed.

Priming, or first filling of canals, should be started by channeling small amounts of water. The water is gradually built up to reach the canal's maximum capacity. The filling of the supply ditches with the first water and flooding of field checks with the first flood water is effected in the same manner with small discharges maintained for 2-3 days and increased to a maximum soon after. Meanwhile, the compatibility of the water conveyance and distribution networks is closely watched. The gates and control structures are tested for easy and convenient operation. Checking the competence of and applying the first water to a rice system laid in tracks of saline soils where leaching may damage the check levees and deteriorate the check level surfaces requires special attention.

Once the rice system is put to use for commercial rice production, its seasonal uses include the following operations:

(1) preparation for the current-year cropping season which consists of cleaning the canals and ditches, maintaining roads and waterworks, delivering flashboards, installing panels, stop-planks, water-gage meters, depth stakes, and communication facilities (telephone);

(2) water management throughout the current growing period; and

(3) preparation for the winter, i.e. laying up all hydraulic structures, with the provision for drainage and diversion of the surface runoff.

The application of the first flood in subsequent years is as important and laborious as in the first year the irrigated-rice system was put to operation. Being a key operation in rice farming, it requires a prior,

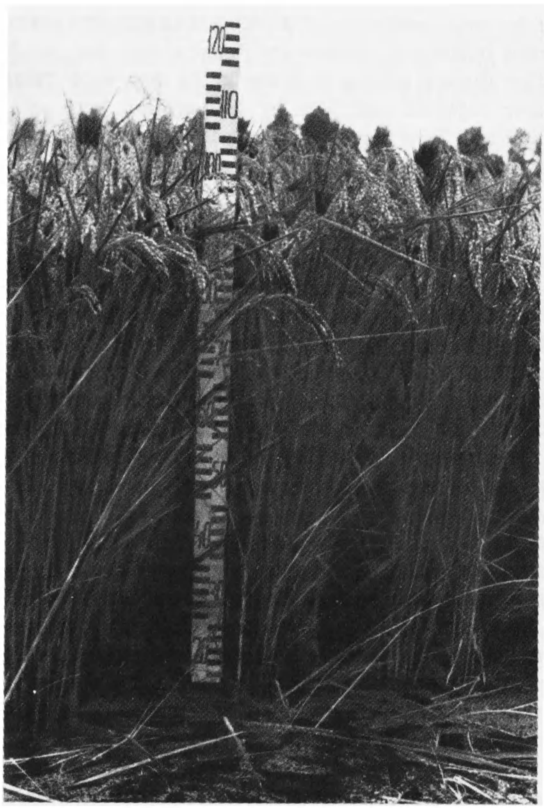


Fig. 14. A depth stake

careful examination of canal banks, check levees, etc. It is necessary to clean and desilt supply ditches, to check gates and shutters, put in place flashboards and depth stakes to ensure precise control of the water depth in each check and rice paddy. To gage the water level in a paddy or check, a depth stake (Fig. 14), which is a wooden plank 5 cm wide and 35-40 cm long with depth indication nails or bands spaced at 5 cm, is driven into the soil. The stake is set at first flooding so that the lower band, i.e. "zero", showing the water surface when half the paddy is flooded, is actually at the average elevation of the ground surface. The depth of water in the

check can also be gaged using depth indications marked out on the turnout structure.

In pre-irrigation or flush irrigation, the water streams are maintained large but not so large as to cause scouring of the soil and washing out of the seeds. Subsequent inflows are controlled as specified or desired.

Practice in the development and use of the engineered ricelands indicates that to be economically feasible the rice system should be constructed to cover an area not less than 500-600 ha. Small-scale rice-irrigation systems are less effective, particularly where saline soils are involved. Rice operations on a small scale and on saline soils lead to the salinization and waterlogging of the adjacent land areas, and the prevention of this may require large expenditures for the construction of protective and drainage ditches.

Presently, research and development is under way to automate the processes of water management (distribution and recording) in rice systems, replace the open-ditch irrigation by pipeline irrigation, and improve surface leveling by underwater puddling of the soil in field checks.

Rice in the Soviet Union is an artificially irrigated lowland crop seeded directly onto the check. Nursery transplanting is not practiced.

Modern cultures of rice in this country rely on the policy of ever increasing rice production based on the use of engineered rice systems, mechanization, fertilization, and the latest advances in agricultural sciences and practical rice farming.

Each of the country's rice producing areas has incorporated practices of growing and harvesting rice which assure high yields (6-7 t/ha) of good-quality paddy rice.

Crop Rotations

In most rice growing farms crops are rotated because under continuous cropping with rice the soil becomes depleted in fertility and organic matter. The resulting deterioration of the physical condition of

the rice soil makes cultivation difficult and the soil becomes infested with weeds and diseases that reduce the yield and quality of the rice grain.

Proper choice and establishment of a rotation program is very important for maintaining high and stable production, controlling weeds and red rice, increasing the irrigation water and land use efficiency, as well as the use of farming machinery and labor. Rice rotations help maintain and improve soil tilth and productivity between rice crops, provide nutrious forage for livestock on the rice farms and increase the total agricultural output per hectare of riceland. The preferred system of cropping for any farm depends on the soil type, local climatic conditions, and economic considerations. In any case, both the riceland and rice grower should benefit from crops rotated with rice. Rotational crops are selected so as to help eradicate weeds, reduce populations of injurious pests, control diseases, and lower production costs.

Although the biology of rice makes it superior to other crops in that it responds well to repeated or continuous cropping, rice in this country is rotated with other crops for the reasons discussed earlier. Rice rotations are also feasible because the increase in rice yields, despite a smaller proportion of cropland in rice each year due to rotation, is sufficient to maintain or even increase the total rice production on rice farms. A high and stable yield of rice under continuous cropping can be, however, obtained only with heavy applications of commercial fertilizers. The USSR Rice Research Institute has reported that the 27-year average yield of rice grown in a six-year rotation was by 1.73 t/ha more than when rice was grown continuously. Rotating rice with other crops is 1.5 times more economical than maintaining a continuous rice culture. In establishing a cropping system, a four-year rotation of rice gave 0.45 t/ha, or 10 percent more rice than the first yield. The yields of rice declined 0.47 t/ha within the same period under continuous cropping. In rotation experiments in the USSR Far East, the yield of rice in a seven-year rotation system was found to be 1.5 times that of rice under continuous cropping. Similar results were reported from the Uzbek SSR Rice Research Institute.

Continuous planting of lands to rice leads to heavy infestation of riceland with the rice-culture related weeds, to the detriment of the soil's physical condition and depletion of its fertility.

The beneficial effect of crop rotation on the rice yields can be attributed to many factors. First, rotations enrich the plow-line soil layer in organic matter and eliminate aquatic and other injurious weeds. Rotations facilitate oxidation of the chemically reduced nutrients, improve porosity, reduce the bulk mass by improving soil texture (less amount of particles smaller than 0.25 mm). They are also helpful in controlling insects and

diseases and providing better opportunities for surface leveling through timely operations. On commercial rice farms, rotations ensure comparatively high and stable grain yields (Table 2).

Table 2. Rotation vs Continuous Cropping (the Kuban area)

Farm	Average yield of rice, t/ha				
	1968	1969	1970	1971-1975	1976-1980
			Rice rotation		
The USSR RRI* seed farm	5.53	5.66	6.39	6.10	6.20
Demonstration farm	5.57	5.23	6.23	6.40	6.23
			Continuous cropping		
Commercial rice farms	4.83	4.07	4.56	4.70	4.40

* The USSR Rice Research Institute.

Rice rotations in this country were first used in the old Kuban delta lands which were formerly overgrown with boggy-reed vegetation. An 8000 ha area had been developed for rice and six- and seven-year rotation systems were tried on its low-productive, overmoist and partly salinized soils. In the years 1971-75, average yield on the rice farms there was 6.4 t/ha and in 1975 alone, 7.05 t/ha. The rice production figures for the period between 1976-80 in the fields given the basic fertilizer treatment in this area, depending on the crops grown ahead of rice, may seem appropriate here:

Rice following	*Rice yields, t/ha*
2 years alfalfa..	6.42
Rice..	6.04
Fallow-grown pulses...............................	5.52
1 year rice..	5.43
2 years rice...	5.15
3 years rice...	5.05

Rice rotations have come into use also in the new Kuban delta ricelands to benefit the rice growers with 5.5 t/ha and more rice, which is 1-1.5 tons more than the average yield on the neighboring farms where rotations are not yet customary.

Cropping systems or rotations have been used by many rice farms in other rice producing areas of the Soviet Union just to demonstrate that crop rotation is essential to ensure rice yields of about 6.0 t/ha, or even more.

Cropped Land Structure

Under a rotation program it is sought to use a maximum of cropland in rice following crops that are proven the best predecessors, or forecrops. Such crops for rice are those that improve soil productivity and help the rice grower obtain good returns from a hectare of cropland. For this purpose, the irrigated ricelands should for the greater part of the year be preferably used for raising high-yielding crops. Since livestock has been extensively developed in most rice-growing areas, such crops are grown basically for feed purposes. In this way, crop rotations are a useful tool in matching up the cultivation of rice and livestock raising.

Usually the rice systems are designed and engineered for a particular rotation pattern. The choice for a cropping pattern is therefore very important, the determining factors being agricultural specialization, soil type, water and drainage conditions in the locality, and the agronomic function of the rotation system. The idea of crop rotation implies that crops be periodically changed, e.g., flooded rice is followed by a dryland crop. Such alternation of crops is mutually beneficial because it helps eliminate the deteriorative effect on the rice soil of extensive floods by allowing the soil to dry out when it is in a dryland crop. The cropping systems should be selected so that the proportion and the order of crops in the cropland are easily adaptable to different economic situations without readjusting the irrigation facility layout. Research and farming have proved that long-time rotations, such as the seven-, eight-, and nine-year rotational programs, are most suitable in this respect.

Of the numerous long-time cropping systems, the eight-year rotation with perennial grasses and seeded or cultivated fallows is preferred as the most flexible one. Under such a cropping pattern, 62.5 percent of the land is used for rice, this proportion being easily increased to 75 percent when necessary. The rice soil benefits from this system in receiving a double amount of organic matter, first from turning under the perennial grasses, then from the annuals. In addition, the eight-year rotation system pro-

vides better opportunities for the basic land-forming and leveling operations in each field check. In most rice producing areas, this cropping pattern has been the basis for design and construction of new riceland developments. Also, other scientifically-grounded cropping systems involving rice for various periods have been in use on rice farms of other locations in the Kuban delta lands.

The Krasnodar Territory. Many rice farms use the eight-year rotation with the following orders and frequency of crops: first two years, perennial grasses (alfalfa, clover); third to fifth year, rice; sixth year, seeded fallow; followed by two annual crops of rice (with 62.5 percent of the land being used for rice; 25 percent, for perennial grasses; and 12.5 percent, for cultivated fallows, under the system). About one-fourth of the cropland in the Kuban delta is in a seven-year rotation: first and second year, perennial grasses (alfalfa, clover); third to fifth year, rice; sixth year, cultivated fallow, and seventh year, rice; or first year, cultivated fallow; second and third year, rice; fourth year, other grain crops overseeded with perennials; fifth year, grasses, and sixth and seventh year rice (with 57.1 per cent of land in rice, under the system). Where the long-time rotation is impracticable, but the agronomic practices are advanced, and labor and power resources are plentiful, the rice growers choose to use short-term cropping systems, such as the three year rotation: first year, seeded fallow and second and third year, rice (with 66.7 percent of the cropland in rice); and four-year rotation: first year, cultivated fallows and three years in rice, i.e. three-fourth of the time the land being used for rice, under the system.

The Don River and Cis-Caspian Lowland. Depending on local conditions and economic considerations, rice growers here may choose between six-, seven-, and eight-year rotation systems.

In a six-year rotation, the frequency of crops is: first and second year, perennial grasses; third and fourth year, rice; fifth year, seeded fallow (spring grain crops) and sixth year, rice (with 50 percent of land in rice, 33.4 percent in perennial grasses, and 16.6 percent in seeded fallows). Also, row-crops and pulses may be fallow-grown in some localities.

The seven-year cropping systems recommended for these areas are similar to those used by the rice-growing farms in the Northern Caucasus. The fallow-grown crops may vary with the locality from winter wheat, pulses or spring barley in eight-year rotations (with 62.5 percent of land in rice) to vegetable crops, in seven-year rotations.

The USSR Far East. In the Monsoon climate of the Far East the cropping patterns vary. The eight-year rotation may have a different order of crops depending on the depth of snow pack in the winter. Thus, in

localities where snow cover is permanent, an eight-year rotation may be: first to third year, rice; half of the fourth year, green manure crop, the other half — maintenance of the irrigation facilities; fifth and sixth year, rice; seventh year, barley or oats over-cropped with clover; eighth year, clover (with 62.5 percent of the land in rice). Where snow is marginal, the order and frequency of crops is: first to third year, rice; half of the fourth year, green manure crops, the other half — maintenance of the irrigation facilities; fifth and sixth year, rice; seventh year, cultivated fallow; and eighth year, forage crop, the percentage of land in rice being the same. In other localities, recommendations are for a seven-year rotation as follows: first year, grain crop; second year, feed crop; third and fourth year, rice; fifth year, green manure crop; sixth and seventh year, rice (with 57 percent of cropland being used for rice). A six-year rotation allows for one year in grain crop, two years in rice, one year in soybeans for green manure and two years in rice (with 66.7 percent of land in rice). The practice for newly developed ricelands has been a four year rotation consisting of three years in rice followed by half a year of green manure crops and the other half used for maintenance of the irrigation facilities (with 75 percent of land in rice, under the cropping system).

The Ukraine, Uzbekistan, and Southern Kazakhstan. With allowance for the local traditions and climate, the cropping patterns are essentially the same but may vary in length from four to nine years, also in the order of crops and in the proportion of land in rice, which may range from 43 to 66.7 percent. Whatever the order and frequency of crops in rotations, rice growers have to follow the general tendency of allotting a maximum and economically feasible proportion of the land to rice as a staple culture, and grow catch-crops on it in between rice croppings.

Intensified Cropping Systems

Because of the high cost of land development for rice, one way to ensure good returns from a hectare of irrigated land is by putting the riceland to intensive agricultural use. Considering the limited geography of rice in this country, another way is to extend the acreage for rice in a rotation in addition to increasing the yield of rice through improved agronomy and superior varieties. Research on rotating rice with other crops has proved it possible to repeat rice cropping (up to four years) in the same field. Obtaining high and stable yields under such a system of cropping requires periodic incorporation into the soil of organic matter, optimum applications of fertilizer, good water management, sufficient

treatment of the fields with herbicides, and adequate agronomic practices. Rotational experiments conducted by the USSR Rice Research Institute indicate that the yield and gross output of rice can be increased through using rotations, making better use of perennial grasses, increasing to more than three years the length of repeated cropping of rice after perennial grasses, and through growing catch-crops (Table 3) between rice croppings.

Table 3. Rotation of Rice with and without Catch-Crops
(the USSR RRI field experiment with perennials, and 66.7% of land in rice)

Experiment treatment	Rice yield	Total agricultural output, ton per rotational hectare			Coefficient of land use
		Rice grain	Feed units*	Digestible protein	
Rice following fall-plowed alfalfa; no catch-crop	6.95	4.63	7.61	0.6	1.0
Rice following spring-plowed alfalfa after first haycut plus catch-crops for green manure	7.25	4.84	8.35	0.71	1.3

* The Soviet feed unit is based on oats, not barley.

The eight-year rotation system developed by the researchers for the Kuban delta ricelands can be considered as intensified rotation with 75 percent of land in rice (Table 4). The coefficient of land use under this system increases from 1.25 to 1.75 due to growing catch-crops and better use of perennial grasses.

Forecrops. The growth of agricultural plants and cultural methods used for soil cultivation, and particularly applications of water and fertilizers, cause various changes in the physical, chemical and biological properties of the soil. This in turn affects the growth and development of crops that are grown on the same field the following years by increasing or decreasing their yield. The knowledge of how the individual species or groups of plants may influence the crop grown in alternate years is very important for appraising these plants or species as the forecrops, for setting the proper order and frequency of crops in a rotation.

Table 4. Intensified Eight-Year Rotations (Recommended for use in the Kuban area)

Year	Traditional practice	Recommended practice		
1-2	Spring-sown perennial grasses as pure stand or over-crop	Spring or winter crop with spring or summer-sown grasses	1st year, spring-sown perennial grasses in pure stand; 2nd year, rice	1st year, seeded fallow (annual grasses) with catch-crops; 2nd year, rice
3-5	Rice	Rice	Rice with catch-crops	3rd and 4th year, rice; 5th year, pulses (winter or spring) with catch-crops
6	Seeded fallow (winter or spring pulses)	Rice with catch-crops	Rice	Rice
7-8	Rice	Rice	Rice	Rice
Crop	**Cropped land structure, %**			
Rice	62.0	75.0	75.0	75.0
Perennials	25.0	12.5	12.5	—
Annuals	12.5	12.5	12.5	25.0
Catch-crops	—	25.0	50.0	75.0
Coefficient of land use	1.0	1.25	1.5	1.75

Table 5. Crops Recommended in Rice Rotations
(for selected rice areas of the Russian Federation)

Rice growing area	Perennial grasses	Cultivated fallows	Catch-crops for green manure and green chop grown	
			in fallows as summer crops	in fallows and rice fields as winter crops
The Northern Caucasus	Alfalfa, clover, and mixtures of these	Winter wheat plus winter pea; winter wheat plus winter vetch; pea plus barley; pea plus oats; vetch plus oats; winter barley	Spring pea, peavine, vetch, mustard, spring rape-seed in pure stands and mixed with oats	Winter rye, winter rape-seed mixed with winter pea
The Lower Volga	Alfalfa	Winter rye mixed with vetch for green chop	Spring vetch and oats mixture	Winter rye, winter vetch in pure and mixed stands
The Far East	Clover and timothy grass	Soybeans	Soybeans	—

It has been proved by many tests and practical rice farming that perennial legumes, fallow-grown annual legumes and green manure crops, leguminous-gramineous mixtures and cruciferous plants,and catch crops grown for seed and green manure are best for growing in rotations ahead of rice (see Table 5).

For other rice-growing areas, the crops preceding rice in rotations are essentialy the same. In addition, sweet or sour clover, crimson clover mixed with berseem or Egyptian clover are sown in Kazakhstan, Uzbekistan and Turkmenia. The Sudan grass and spring wheat are grown in fallow fields and as catch crops in the Ukraine and Kazakhstan; while corn (maize), sorghum, joughara mixed with mung beans, sweet clover and vetch-oats mixtures are sown in Kazakhstan, Uzbekistan and Tajikistan.

The rice soil benefits much from alfalfa and clover if grown for two years. The grasses improve the physical condition of the soil, increase the content of organic matter and soil productivity. Perennials facilitate the conversion of almost insoluble phosphorus compounds into readily soluble ones whose quantities tend to increase with the age of grasses. With a two-year old grass cover, the soil has a maximum of available phosphates. In rice rotations the total yield of alfalfa hay (four cuts) may reach 8-10 t/ha with the cost of one feed unit much lower than that of annual legumes. High yield of alfalfa in rice rotations is due to good agronomic practices including check-flood irrigation or sprinkling and fertilizer applications.

The beneficial effect of alfalfa on the rice soils is higher when the two-year old grass is left overwinter to be turned under the following spring after the first cut of hay. In this case, it gives additional 25-30 t/ha of green matter (5 tons on dry matter basis) before the field is sown to rice. The method of turning under alfalfa in spring has become customary with the rice farms in the Kuban rice areas ensuring stable yield of good-quality hay in addition to 5 t/ha of early or mid-season rice each year, and increasing the organic matter in the soil in the form of roots and other plant debris. The higher the yield of perennial grasses grown ahead of rice in rotation, the higher their beneficial effect on the rice soils and, consequently, on rice yield. Grasses therefore must be given the best agronomic care including seasonal irrigation and fertilizer treatments combined with soil slitting to produce highest yields of hay already in the first year.

Modern agronomic practices and adequate timing of optimum nitrogen and phosphorus fertilizer applications make it possible to maintain and sometimes increase the yield of rice grown three years continuously after grasses.

The yields of rice in an eight-year rotation depending on the forecrop were as follows (the data of the USSR RRI):

Rice following:	*Rice yield (average for several years), t/ha*
Grasses turned under after the first cut of hay........................	6.36
1 year rice..	5.40
2 years rice	6.00

Practical rice growing in the Kuban ricelands showed that alfalfa grown for two years ahead of rice and plowed under in the spring before seeding rice gives assured 5.0-5.5 t/ha of rice grain, and with fertilizers, up to 6.0-7.0 t/ha. Similar yields of rice in grassland broken at fall are attainable only with the application of 90-100 kg/ha of nitrogen fertilizers and phosphates (P_2O_5).

Fallowing. The chief aim of fallowing fields is controlling weeds, check land leveling, and reshaping and maintaining water structures. But because the land development for rice is costly, it is unwise to allow the land to lie idle, and hence pure fallowing is not encouraged. The fallow fields are therefore seeded or cultivated which permits the chief aim of fallowing to be achieved plus the fallow-grown crops additionally gathered.

Seeded or cultivated fallows are fields used for growing various agricultural crops which when ripe leave fields free from plants soon after harvest for the land-leveling operation. Such crops in the Northern Caucasus are winter wheat mixed with winter peas or vetch grown for hay or green chop, spring vetch mixed with oats, winter and spring peas mixed with oats or barley, and winter barley. The fallow-grown crop in the Lower Volga rice farms is mostly winter rye mixed with vetch for green chop. In the Far-East ricelands such crop is soybeans.

The use of mineral fertilizers for the fallow-grown winter crops is mandatory in all the rice producing areas. The rates vary with the area and soil productivity. The soils in the Kuban delta lands require 120 kg N in addition to 90 kg P_2O_5 per hectare applied as basal fertilizer during the fall plowing for grains in pulses. Nitrogen applications are split into 90 kg/ha at seedbed preparation and 30 kg/ha as an early dressing.

For early spring crops, such as barley, wheat, peas and oats mixed with vetch and peas, the fertilizers are applied at seedbed preparation, or at harrowing.

The yields of vetch and oat mixtures sown in fallows for hay are about 5 t/ha; winter wheat and peas produce by early spring 3 to 4 t/ha and winter peas sown in autumn produce up to 3 t/ha of nutritious green matter.

All these crops are however susceptible to excess moisture. Crop failures may result from too much water held in checks after heavy rainfall and cloudburst unless adequate drainage is provided.

The choice and composition of fallow-grown crops relies on the economic considerations, availability of seeds, and the possibility for annual land-leveling in the checks, which is a key operation for obtaining high rice yields the following season. In selecting and allotting lands to the accompanying crops of rice rotation and fallows, the physical condition of the flooded soils is particularly important. Alfalfa, barley, corn and peas do not grow well where drainage is poor and the water table high. Their yields are low from excess water and poor thin stands. Adequate drainage is therefore the only remedy from waterlogging and inundation of rice fields and the adjacent areas which are in dryland crops. Of the crops which can tolerate high ground waters, crimson clover, berseem (Egyptian clover), and mung beans are the most tolerant.

Benefits to the staple rice culture from cultivated fallows in the rotation are high only with good weed control, proper grading and leveling of land, and increased organic matter in the soil due to fallow-grown annual legumes and grasses. The intensive use of land through seeded fallows makes possible double cropping of riceland so that two crops are harvested the same year, provided all operations are expertly timed.

Catch-crops. Double cropping implies growing catch-crops for use either at fall or early next spring as feed or green manure the same year after the main fallow-grown crop is harvested, field leveled and given the semi-fallow tillage. Growing catch-crops is also important for improving soil productivity and rice yield. The name catch-crop applies to crops grown the same year following the staple crop and intended for feed or green manure. They are also known as *stubble crops*. The term is also applicable to crops sown in the spring into the cover crops to keep growing still for some time after the cover crop is harvested. Such crops are also called the *companion* or *nurse crops*; the name applies to crops sown in summer or in the fall following the staple crop and harvested for feed purpose the following spring before a main crop is sown, and known as the *wintering crop*; and also to crops sown on fields free from the previous crop harvested early in season for green chop, sillage or hay, and sometimes called the *postharvest crops* which elsewhere can be grown as the main crop.

The agricultural plants selected to be grown as catch-crops should be high-yielding and early-maturing recommended for this or that area, and well adapted to heavy and periodically flooded soils. Among such crops are pulses (winter and spring vetch and peavine), winter rye, winter wheat, barley, oats, spring rapeseed, all sown in pure or mixed stands.

In the Northern Caucasus and the Lower Volga rice areas the fallow-grown catch-crops are sown in the summer or fall and thus are called sum-

mer crops. The same crops to be grown in rice fields are sown as winter crops. In the rice producing areas of the USSR Far East the catch-crop is soybeans (when grown in fallows it is for green manure, although soybeans can be grown for grain).

Winter rye is good as a catch-crop. Some of its winter varieties are winter-hardy and shoot out well early in the spring at low temperatures (close to zero), producing fairly good yield of nutritious green matter, so valuable early in the spring for its vitamins.

In many rice-growing areas of this country and particularly in the Cis-Caspian Lowland, rotational crops are grown in saline soils. In such cases, adequate drainage and importation are necessary to avoid waterlogging, inundation and salinization of the land in accompanying crops and grasses that are adjacent to rice fields on the one hand, and make the best use of the rotation, on the other. Of the accompanying crops, peas, oats and corn are less tolerant to salts than are rye, wheat, sorghum, and particularly alfalfa. Gourds and melons tolerate better high concentrations of salts. Soil moisture content is an important regulator of the degree of salt tolerance of the rotational crops. The higher the moisture content, the more tolerant the plants to salinity during their early development.

To provide high and stable yield, each rotational crop in a rice cropping system should be grown under optimum agronomic conditions. It has been established that the rice yield to a large extent depends on the productivity of the preceding crops. Thus, yield of rice following one year alfalfa, depending on its crop of hay, was as follows (data of the Uzbek SSR Rice Research Institute):

Alfalfa yield (dry matter), t/ha	3.52	6.61	7.78	7.91	11.30	11.90
Rice yield, t/ha	2.72	3.74	4.50	5.78	5.43	5.93

Good timing of catch-crops is also important in a rice rotation. It is advisable that in the rice fields which are planned the following season for catch-crops, rices are early-maturing and sown in the current year as early as possible. In that way the crop of rice is ready to harvest much early giving the grower time enough to prepare the land for catch-crops of the following year.

Land Preparation

Tilling soil for rice is not much the same as tilling for other cereals and dryland crops. Its principal aim in rice production is to obtain high yields of rice through improving the soil and taking advantage of its potential productivity.

While the dryland crops require soil nutrients in the oxidized form, the rice plant benefits more when the nutrients are chemically reduced or deoxidized. The dryland crops require that the capillary-noncapillary porosity ratio (determined by the water-stable soil structure and soil moisture brought to capillary capacity) be optimum, while this soil parameter for rice is practically unimportant.

Nutrition of the rice plant is in large measure assured by inundation during part or all of the growing period. Flooding is very much essential for optimum grain yields, that is why the ideal soil types for rice production are those that conserve water. Most rice soils, often referred to as heavy soils because of their high clay and silt content, present special soil management problems that are overcome through soil cultivation practices intended also to help make the best use of the natural soil potential. These measures include tillage and seedbed preparation, maintenance of organic matter and soil texture, drainage for successful mechanized rice operations, cultivation of other crops in rotation with rice, fertilizer applications, use of green manures, and weed control.

Soil tillage practices vary from place to place depending on soil type, climatic conditions, crop that precedes rice in rotation, physical condition of the soil, character and degree of field infestation, herbicides used and other factors. Tillage in rice production pursues many purposes which are generally aimed at:

(1) forming a sufficiently deep and biologically active plowline layer by working the field several times over with various types of plow;

(2) creating conditions in the plow-line that help immobilize soil nutrients, i.e. regulate oxidation and reduction through loosening, drying and aerating of soil;

(3) wetting the rice fields that are to be sown at early dates and to a greater depth so as to establish the moisture content sufficient to bring about emergence of rice seedlings without additional flush-irrigation;

(4) preparing the riceland with a soil structure that will ensure a uniform coverage and germination of seeds, good stand establishment and further development of the plant during growing season;

(5) controlling weeds, pests and diseases of rice and other rotational crops by plowing in the fall one time over with a chisel and a second time in the spring with a mouldboard;

(6) precise leveling of the field surface (to within $\pm$ 5 cm from the median plane of the rice check surface) to maintain desired depth of flood water in the field and to drain as rapidly as required;

(7) covering organic and mineral fertilizers at desired depths;

(8) preparing a suitable seedbed for rice.

Basic Soil Treatment

The above aims are achieved through proper combination of the basic and supplemental land preparation operations before seeding rice.

The basic soil treatment includes *plowing the riceland in the fall* with the bottom or disk plow to obtain a complete inversion of the soil layer. Fall plowing has been recognized as a key operation for obtaining high yields of grain. Depending on the crop that precedes rice in the rotation, it may be desirable to choose to plow the land in the fall or early spring. However, fall plowing has advantage over spring tillage in many respects. The riceland plowed in the fall is not so overwet in the spring and the soil absorbs water readily leaving no pools or puddles of water in the check. The physical condition of the soil by spring time is rather satisfactory: it sticks less and cuts well forming a better tilth, and is easy to prepare for seeding by disking or harrowing the following spring. Fall plowing extends the period for aerobic processes occurring in the soil which are restricted to 15—20 days only when the soil is plowed in the spring.

Long-term experiments have indicated that the physical properties of soil in the plow-line layer are markedly improved during the time from deep plowing in the fall to seeding in the spring. The reduced density and increased porosity of the soil due to fall plowing facilitate oxidation and eliminate the aftereffects of the accumulated lower-oxide compounds. For this reason, fields plowed in the fall are left rough and cloddy overwinter, and are never harrowed. In the winter, clods are subject to alternate wetting and drying, freezing and thawing. This helps improve the physical characteristics, intensify the chemical and microbiological processes in the soil. Only a limited amount of land work may be necessary in the spring to prepare a suitable seedbed because the soil is in fairly good physical condition after fall plowing.

Fall plowing is also an important means of controlling aquatic weeds in the rice fields particularly the marshy weed growth. Most weed roots and tubers are undercut and brought to the surface with the inverted soil where they lose their vigor and die during the winter. The previously compacted soil is loosened, forming in the top (0-10 cm) the layer which contains a substantial proportion (up to 60-70 percent) of particles from 1 to 10 mm in diameter, favorable for rice. This leaves very little land preparation for a good seedbed in the spring.

The time to begin basic soil treatment depends on the completion of the harvest and post-harvest operations, soil dryness and cleanness. Delays in this operation are undesirable because rainy weather in the late fall may prevent tillage, or deteriorate the condition in the plowed-up

layer of soil. It is advisable to put rice fields to plow 5-10 days after harvest. At this time, the fields are well drained, the topsoil is free from gravitational water, and is mellow.

Usually, plowing starts from the most elevated areas in the rice system where the soil dries promptly, and in the fields which will be sown to rice at early dates the following spring and the seed will be planted deep in the soil. The earlier the rice fields are plowed in the fall, the better. This leaves soil open to air oxygen for a much longer period and aids in the decomposition of organic matter. Decomposition facilitates conversion of the nutritive substances into the forms usable by the rice plant.

In the years when the winter is mild and rainy, the effect from fall plowing is however reduced. The soil remains a long time overmoist, and is subject to baking or crusting. The oxidation processes are slow. To avoid subsequent difficulty in preparing the seedbed, the land is plowed in the spring. It is disked and harrowed as soon as possible after plowing to break up large lumps and clods and to prevent baking, also to dry and aerate the soil, and form a desirable soil structure. Heavier soils require more intensive tillage when plowed in the spring time than when plowed in the fall, or early winter.

Generally, the depth of fall plowing depends to a large extent on the soil type and class, depth of organic matter, degree of salinity, infestation, and on the species of weed plants. The depth of plowing is greatly influenced by the type of soil. In plowing chernosem (blacksoil) in the Northern Caucasus rice areas, the best results are obtained with mouldboard plow which inverts the layer from a depth of 20-25 cm. Very deep plowing is unsatisfactory because of cloddiness that leads to excessive non-capillary porosity. Besides, productivity of the soil is reduced by gley and other undesirable soil material which is brought to the surface, resulting in lower yield and poorer weed control. Experiments on the depth of tillage have showed that plowing deeper than 25-27 cm even the soils in which organic matter is profoundly deep is uneconomical because of unreasonably high cost of labor and power requirements, and is also unfeasible from the agronomic point of view.

Shallow plowing in the fall is not advisable either and should be avoided. When the soil is disked or otherwise plowed to a shallow depth, the layers which are intact by tillage remain compact and poorly aerated during all of the growing season. The depth of plowing is smaller for the meadow-boggy, duff-gley soil in which organic matter lies shallow. Such lands require that plowing be performed very carefully not to bring the gley material to the surface. Deeper tillage will affect the productivity of the soil and reduce yields. Peat soils are usually plowed to 22-25 cm.

Rice fields may be badly infested with boggy plants such as cattail flag, water plantain, bulrush and spike rush, and reed. The depth of the weed rhizomes or tubers may vary from 10-12 cm to 25 cm. In such cases, the fields are usually worked with a mouldboard that cuts the soil at somewhat larger depth and brings the rhizomes to the soil surface. In the spring, the roots and tubers are raked and burnt.

In tilling one and the same field in the fall, it has been customary to plow in one year and plow out the following season to maintain the check surface as level as possible. It is also desirable to alternate the direction of plowing, i.e. one year over and along the field gradient, and across the field the following year.

In the fall, saline soils are tilled to a depth where soil has no organic matter with a mouldboard which has an attachment to loosen the subsoil for one pass. This helps break the compacted underlying layers of the soil and improve its physical properties. Once in three to five years it is advisable to plow such soils to 45-50 cm without soil inversion to prevent the topsoil from capillary rise of the ground water which can be high in mineral matter, and to increase deep percolation, aeration and processes of oxidation. Mouldboardless plows have been found satisfactory on this type of soil too, but the accompanying loosening of subsoil remains obligatory with this operation.

Deep plowing with a mouldboard and staged tilling have produced satisfactory result on rice grown in saline soils of the Sarpa dry bottomland (Cis-Caspian Lowland). Plowing to 13-15 cm with the inversion of soil layer has been found advantageous for salty ricelands in the Lower Volga. The three-year average yield of rice there was 5.73 t/ha, which is 0.74 t/ha more than when the soil was plowed to 20-22 cm. Fall plowing in Kazakhstan gave 0.1 t/ha more rice than plowing in the spring. The rice fields in the far-eastern areas are plowed in the fall to a depth of 20-25 cm so that the seeds or other vegetative reproduction organs of weeds are turned deep under.

Timely treatment of riceland in the fall is important for adequate drying of soil. This applies still more to the far-eastern ricelands where the water table is rather high (30-40 cm from the ground surface). Compacted by floodwater, the top soil communicates through capillaries with the ground waters. When the floodwater is withdrawn, the ground water comes up to the evaporating surface of the field check by capillary rise. This delays the drying, and chemical reduction processes in the soil which continue to late May, early June. Fall plowing interrupts the capillary communication of the topsoil with the underlying strata, makes easy the entry of warm air into the soil, and facilitates drying and oxidation.

The implements used for the basic treatment of ricelands may vary from the tractor-mounted and semi-mounted to the tractor-pulled types of plow.

Tilling Grassland for Rice

Cultivating and turning under perennial grasses has been found beneficial for rice and other crops grown in rotation through more moisture and plant-available nutrients accumulated in the soil under the grass cover. In working a grassland of alfalfa, time and depth of plowing are important factors for efficient use of soil fertility improved by this perennial.

The earlier practice was to break up the grassland that had been for two years in alfalfa only in the fall. To intensify farming and use more grass for improving the productivity of soil and to increase rice crop, alfalfa is now left overwinter for the third year so that the grassland is plowed for rice in the spring after the first cut of hay. Spring plowing of grassland extends the period of decomposition of organic matter stored in the soil. Besides, this gives additional 20 t/ha of good-quality green forage preparatory to plowing and preparing seedbed for rice. In treating the grassland for rice in the spring it is required that the cultivation of soil and plowing down the post-harvest grass residue be as thorough as possible to provide favorable conditions for mineralization of the plant debris. It has become customary to plow the fields of perennial grasses, predominantly in alfalfa, in the spring to a depth of 18-20 cm. The depth may be increased to 20-22 cm the following season, and to 22-25 cm during the third, and the following years to make the best use of the entire soil layer now high in organic matter.

Some rice farms use perennial grasses for annual cultivation (as is recommended for intensified rotations). Such grassland is also plowed in the spring within the shortest time possible after the first hay-cutting. Experience has shown that a year-old grassland plowed in the spring to a depth of 18-20 cm produces 1 t/ha more rice grain than when plowed in the fall, and reduces the amount of pre-sowing land preparation necessary for a good seedbed. In such cases, rice is seeded at an earlier date than usual.

Tilling Land for Fallow-Sown Crops

As has been mentioned earlier, pure fallowing is impracticable under intensified rice farming and so the fields are fallowed when not in rice but seeded to other crops. This practice helps increase the gross agricultural

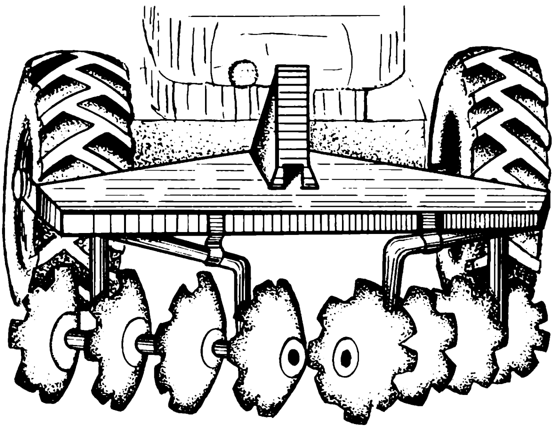


Fig. 15. Mounted disk harrow

output, enrich the soil with nitrogen and organic matter that will benefit rice the following season.

After the rice crop is harvested, the field is plowed and disked preparatory to seeding a crop other than rice. As soon as the fallow-sown crop has been grown and harvested, the fields are usually irrigated with a 10 cm floodwater maintained for about 7 to 10 days to loosen the soil and germinate weed, grass and rice seeds. When the soil becomes mellow, the fields are worked over with a paring plow (topsoiler), but not harrowed. As soon as the soil is dry enough, the fields are subjected to basic leveling or land-forming. The level fields are worked with a disk harrow (Fig. 15) (where necessary they are again flush-irrigated) and are seeded to green manure crops. In the northernmost rice areas the green-manure crops are sown in early spring to the fields that have been plowed and harrowed in the fall. The primary aim of disking is to eliminate weed vegetation, break up clods and lumps left from the second plowing, break and roll down the stubble and level the fields. The fallow sown winter crops, such as rye, wheat, barley, peas and vetch, are seeded at the dates usual for these crops.

Preparing Seedbed for Rice

Presowing soil treatment is an important cultivation practice that usually results in high yields when performed adequately and timely. Presowing operations are aimed at preparing a suitable seedbed with assured

uniform distribution of seeds over the area being drilled or broadcast, good emergence and rooting of seedlings and normal development of the rice plant during the rest of the growing period. The seedbed preparation operations allow the rice field to adequately dry out and form a good tilth with desirable size of soil particles.

In addition, cultivation of soil preparatory to seeding rice destroys the rhizomes and tubers of marshy weeds of rice, brings the field surface to a contour level, and helps to cover the fertilizers applied.

The choice of implements, time and methods of presowing cultivation depends primarily on the condition of soil, weed species, degree of infestation with weed growth, also on the crop that precedes rice, or on other crops in the rotation. It is important not to miss the time when the soil becomes mellow and is good for seedbed preparation. Good choice of the optimum date for seedbed preparation usually reduces the amount of field work and the number of soil cultivations.

Subsoiling or chiseling. Subsoiling has been a regular practice where wet soil is subject to crusting or baking when it dries, and where soils are continuously inundated. Subsoiling or deep loosening of soil is achieved by working one or two times across the field with a chisel plow or cultivator (Fig. 16) to a depth of 16-18 cm. The chisel-type cultivator has been found satisfactory for the purpose. Unlike the bottom-type implements, the chisel leaves no open furrows or back ridges in the field, improves aeration and drying of soil, and destroys weeds that emerge. Also, chiseling promotes immobilization of soil nutrients. In 1980, almost 88.7 percent of the riceland turned in the fall was worked with a chisel. Some rice farms choose to chisel all of their land in rice with a chisel-type cultivator and about 80 percent of their riceland is chiseled in two passes.

Experiments have indicated that chiseling or subsoiling of fall-plowed soils is superior over working such lands with a conventional plow. Thus, early-spring subsoiling preparatory to seeding rice produced 17.3 percent

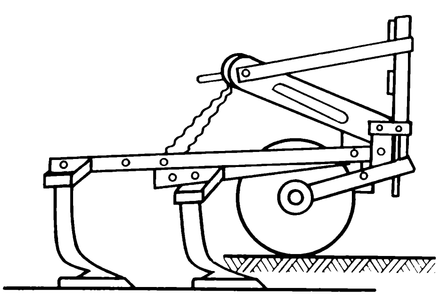


Fig. 16. A chisel-type cultivator or subsoiler

Fig. 17. A rotary drain digger or furrower

more rice (5.08 t/ha) than early-spring replowing or plowing the field a second time with a mouldboard preparatory to seeding rice, and 9.7 percent more than early-spring replowing and chiseling before seeding rice.

Opening check border furrows. It is desirable to make drainage furrows or ditches around the check borders after or during the last land preparation operation in the field (or in the spring preparatory to seeding rice, i.e. during chiseling, disking or replowing) to provide rapid flooding of checks, adequate surface drainage, and to lower the water table.

A rotary drain digger (Fig. 17) or a hydraulic trencher may be used to make these border furrows or ditches normally 0.5 m deep and not less than 0.35 m wide at the bottom. The border ditch banks are weak and need repeated cleaning, reshaping and trimming.

Drawing mole drains. Adequate drainage of rice fields is a means of controlling the rice environment, i.e. water, air and salinity condition of the soil. The main aims of field drainage are:

(1) to lower the water table to a depth safe of 30-40 cm within 2-3 days, and to 50-60 cm within 5-7 days;

(2) to provide the downward movement of water over the entire width in a continuously submerged field check and to remove harmful salts and other toxic compounds from the root zone;

(3) to facilitate soil drainage in the waterlogged and saline land sections

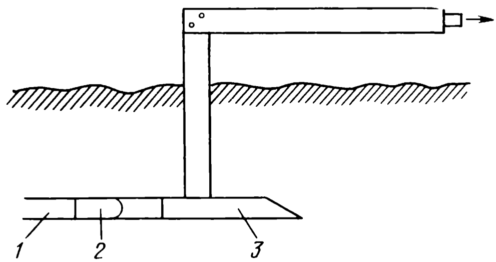


Fig. 18. Drawing a mole drain
1 — mole drain, *2* — expander, *3* — mole (knife)

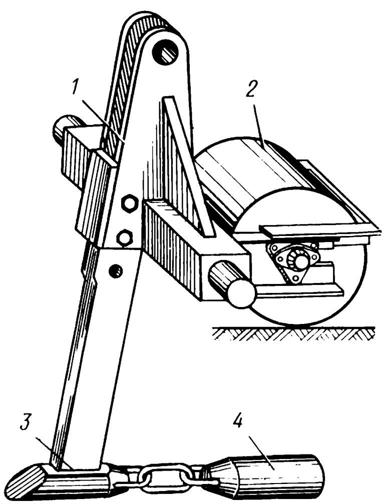


Fig. 19. Mounted moler (the USSR RRI design)
1 — frame, *2* — support roller, *3* — mole blade, *4* — expander

of the irrigated rice system laid in water-permeable soils, and to ensure rapid and adequate drainage of rice paddies when necessary.

The above aims are achieved through unlined underdrains called *mole drains* which are effective in clay soils. Mole drains can be prepared in the fall or spring between chiseling the fall-plowed land and the final seedbed preparation operation.

The mole drain is a circular smooth-walled tunnel 6-12 cm in diameter to carry the water, which retains a moulded shape after a mole plow (Fig. 18) is drawn through the soil. Mole drains are drawn at a depth of

Fig. 20. A roller-type furrower

40-60 cm and spaced 1-4 m apart. They are usually made open to check border furrows or to a catch or cutoff drain. A mole drainer (moler) is normally used to perform the mole drainage (Fig. 19).

Mole drains are an effective and easy means of improving soil drainage in rice paddies and prevent repeated salinization of soil.

Opening temporary surface furrows. To provide timely applications and removal of floodwater in the field it is advisable to open temporary drainage furrows through the check surface at seeding. A ditch digger, roller-type furrower (Fig. 20), or disk furrower following the drill or end-gate seeder may be used to make furrows 15 cm deep and 20 cm wide at the top, which will open to a check border ditch. At harvest, the furrows should be not less than 10 cm wide. Blockage of furrows may be a problem. To ensure perfect drainage of the rice fields when they are ready to harvest, the exact trouble spots must be detected through visual inspection and eliminated.

Tilling fall-plowed fields. The fall-plowed fields infested with reed,

Fig. 21. A roller-packer

clubgrass and other marshy vegetation are usually replowed in the spring 5-6 days before a flood is applied. The fields are worked with a semi-mounted bottom paring plow (topsoiler) to a depth of 12-14 cm to control clubgrass, and somewhat deeper to control reed. This operation helps eliminate all weeds that may by now emerge. Sometimes, replowing leaves the fields rough. The fields are then disked to break up large clods and lumps two or three times over with a heavy disk harrow behind which a spike-tooth harrow is drawn. In riceland with saline soils, the fields operations in the spring are aimed at preventing upward salt movement to the check surface. In addition to disking fields in the spring, they may be worked with a roller-packer (Fig. 21) to firm the soil, help retain moisture and prevent evaporation.

Retilling is done with mouldboard implements. A chisel cultivator may be used to achieve a fairly good weed control. Besides, such fields may sometimes require drawing mole drains or slitting to a depth of 50-60 cm, with 90 cm space between slits.

Current Land-Smoothing or Planing

In rice production, distinction is made between construction land forming (grading), current (seasonal) land-planing or smoothing and basic or reparative land leveling which is performed once in a rotational cycle. Current smoothing of riceland is part of the general preplanting land preparation program. The operation on most rice farms is carried out in dry land although some riceland may be smoothed underwater. The chief aims of this operation are to smooth out the field surface, control weeds in the plow-line layer, form a loose and fine tilth underlain with a firm

pan. A uniform level of the rice field is essential for good rice crop and therefore smoothing land is often the last operation preparatory to seeding rice. It is desirable that a competent surveyor be employed to do the leveling job. If, for some reason or other, the leveling operation cannot be controlled instrumentally, high and low spots in the field may be gradually located by visual inspection during alternate flooding and draining of the field, and mapped with approximate indications of the distance from such spots to the levees or irrigation ditch banks, for further guidance. Often, land-planing performed by a properly chosen pattern (Fig. 22) can be alternated with other operations until the land is suitably level.

Various types of land-moving machines are available to perform the operation. Tractor-drawn land scrapers may be used for small-volume earth-moving. Land-smoothing may be done with long-base land planes (Fig. 23) or heavy and medium-duty land scrapers. Check corners are usually worked with bulldozers.

Obtaining a true or zero contour in a check is important. The precision of planing should be to within ± 5 cm. But these tolerances do not satisfy the advanced agronomy any longer, which for good water control requires a higher precision of land-smoothing (to within ± 2 cm) to maintain a uniform depth of water within the levees, and to drain the check rapidly, if necessary, during the growing season and for harvest.

The mean deviation d_m, cm, from the desired accuracy (± 5 cm) has been suggested for the basic characteristic of the accuracy of land-planing during the construction land-forming and current land-smoothing of

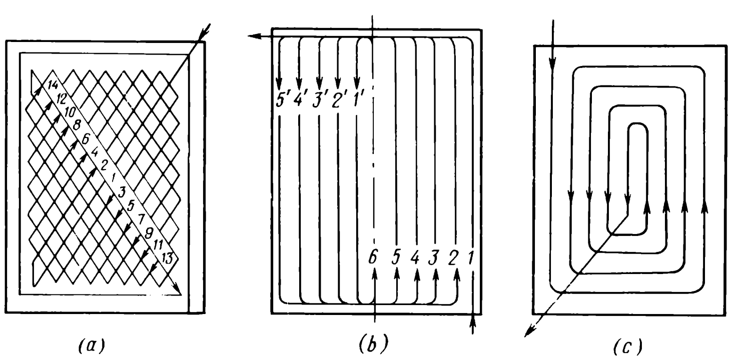


Fig. 22. Land-plane moving patterns
(*a*) cross-diagonal, (*b*) spiral, (*c*) circular

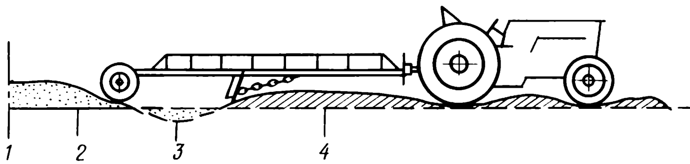


Fig. 23. A long-base land plane or leveler used for accurate smoothing
1 — desired level, *2* — natural terrain, *3* — filled, *4* — to be cut

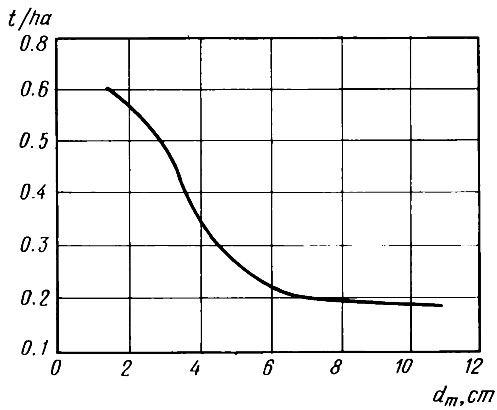


Fig. 24. Yield vs d_m relationship

riceland. The value[1] of mean deviation is calculated from the measurements made at a number of field sampling points which are 20 × 20 m land plots, using the formula

$$d_{\mathrm{m}} = \Sigma h/n$$

where Σh is the sum of deviations at measurement points (square plots in the field) whose absolute value exceeds the desired accuracy; and n is the number of such points.

Land-planing is said to be excellent at $d_{\mathrm{m}} = 0.5$ cm; good at $d_{\mathrm{m}} = 1.0$ cm; and satisfactory at $d_{\mathrm{m}} = 1.5$ cm. Fig. 24 shows the relation between

[1] With Soviet rice growers, is known as the *"level defectness criterion"*.

Fig. 25. Covering fertilizer with a disk harrow behind which is drawn a spike-tooth harrow

the accuracy of land smoothing d_m and yield based on commercial rice yield data [4]:

d_m, cm	12	10	8	6	4	2	0
Yield increment, t/ha	0.18	0.19	0.21	0.26	0.5	0.5	0.6

The above data can be found useful in predicting yield increments per hectare that are used for programming production.

The next operation after land smoothing preparatory to seeding rice is application of commercial fertilizers. Rotary cultivators or disk harrows behind which is drawn a spike-tooth harrow (Fig. 25) may be used to cover the fertilizer uniformly at desired depth that may vary from 0 to 10 cm. In choosing the implements one seeks to prevent cloddiness in the field. Fertilizers applied and covered, the final preparation just ahead of the drill would be working the field with a seedbed-leveling device (float) and a variety of drag or roller-packer put in series to break up lumps in a 0-5 cm deep top-layer to a clod size ranging from 2 to 5 mm, and to firm the soil to retain moisture. Depending on the physical condition of soil, the operations may be alternated or performed for one pass with the implements put in series.

It may not be necessary to replow the fall-tilled rice fields if they are clean and free from weeds. Land-leveling in such fields is usually done with a land-leveler or a long-base land plane; application of fertilizers is followed by disk harrows or rotary cultivators to cover and incorporate them to a depth of 0-10 cm; the soil is smoothed finally with a drag, and firmed with a roller-packer.

Preparing Seedbed for Early and Deep Planting of Rice

Land preparation operations for the purpose are aimed primarily at conserving moisture stored in the soil and include early fall plowing and leveling to prevent drying. Early sowing of rice requires good soils (non-saline), and best crops to precede rice in the rotation (cultivated fallows are good for the purpose, as are grassland, and rice fields newly returned to production after basic land-forming). In the fall, the fields are worked with a mouldboard adjusted so as not to bring the gley and saline subsoil material to the surface. To avoid upward movement of salts and overwetting from autumnal rainfall, plowing may be alternated or done in one pass with drawing 8-12 cm dia. mole drains at 40-60 cm depth opening to a cutoff drain or drainage mains.

Autumnal land-leveling in the Ukraine and the Northern Caucasus is done normally with land scrapers, land-levelers and long-base land planes with mole drains being drawn immediately behind the land smoothing implement. Where leveling operation causes compaction of soil, the land is worked with a disk harrow or a chisel cultivator. A rotary or roller-type furrower may be used to open drainage furrows 40 to 50 m apart throughout the check from the supply ditch to the wasteway to provide a rapid surface drainage of the rain or snowmelt waters in the fall and winter. In conserving soil moisture it is desirable that the last preplanting operation be combined with the covering of fertilizers applied 1 or 2 days before seeding rice. In loose soils, spike-tooth harrows are used to cover the fertilizer. Where the soil is subject to crust formation and compaction, this operation is usually done with a field cultivator, paring plow, or disk harrow in series with a spike-tooth harrow.

In the southern USSR (River Don and Lower Volga), the spring-plowed fields which are intended for deep planting of rice at early dates may frequently need to be flushed. Flushing is then followed by disking the land and firming the soil with a roller-packer after seeding rice to bring up moisture.

In the Far East, the seedbed preparation consists of two stages. During the first stage (early April), the cultivated fallows, grasslands and fall-plowed fields are worked for rice with heavy disks or spike-tooth harrows to bring down weed vegetation and conserve soil moisture. The land is then leveled across the check with land scrapers, and the fertilizer is applied. During the second stage, the riceland is cultivated with a subsurface tiller or disk harrow in series with a spike-tooth harrow after which the soil is firmed with a smooth roller-packer just ahead of the seed drill or endgate seeder.

Fig. 26. Smoothing land in water with a wooden rotovator in series with a spike-tooth harrow

Wet or Underwater Leveling

Preparing land in water has advantage over seedbed preparation in dry land in that it increases the precision of leveling to within ± 2 cm, raises the productivity of labor, lowers power and labor requirements and makes this operation independent of the weather. Leveling land underwater makes the soil more uniform, and clods easy to break to a water-stable size. It minimizes deep percolation losses and accelerates mineralization of organic matter in the soil. Preparing riceland in water makes possible controlling weeds better than when leveling dryland. Harrowing the topsoil underwater brings the weed rootstock, tuber and even weed seeds afloat and easy to collect to the check levees and burn. The remainder, mechanically injured, is left over to rotten and die in the soil.

Establishing a shallow water in the field, plowing the field 12-14 cm deep and disking the field with heavy harrows have been the usual operations with the wet leveling method. The earth in high spots is cut and moved with a land scraper or plane to fill up the low spots. The flood is then raised to 10-15 cm and the land is worked with a disk or rotary harrow or with a wooden rotovator in series with a spike-tooth harrow (Fig. 26) and smoothed finally with a float-leveler (Fig. 27). (In the Ukraine, the land is plowed dry and leveled underwater.)

Underwater land-planing is used for most rice fields in the Central Asia and, to a smaller extent, in the Ukraine, Northern Caucasus, Lower Volga and the Far East.

Fig. 27. Wet or underwater smoothing of rice checks with a float-leveler

On some farms where the riceland is leveled underwater, seeding is done in water by airplane or helicopter into fields which are drained and flooded again (7-10 cm) to renew the water one day after leveling. Soaked or pregerminated seed is used instead of dry seed. Seeding into water has proved as satisfactory as seeding in dry land. The water seeded rice produced 5.84 t/ha of grain whereas the dry established crop gave 5.54 t/ha. The cost of basic and additional land preparation operations plus underwater land smoothing was three times less than when the same operations were done in dryland. Phenological observations have indicated that rice matures 6 to 8 days earlier on the underwater-leveled fields than on the field prepared in dry condition. The checks drain more uniformly and rapidly and dry out 6 to 7 days earlier than the controls, in a field comparison study, prepared in dryland. The rice paddies in checks leveled underwater were less infested with weed growth than the control paddies smoothed dry. Scraper-levelers and trailed floats were used to mud or puddle the soil. The final preparation of check surfaces was done with trailed tooth harrows, mounted disk harrows, rotovator levelers and other implements and machines with active implements, such as a rotary disk or spring(-loaded) harrow.

Minimum Tillage for Rice

Traditional method of land preparation for rice includes a number of separate operations done on a field until a good seedbed free from weed is

prepared and hence the cost of such land preparation is rather high. An attempt has been made at the USSR Rice Research Institute to reduce the number of separate operations (passes) preparatory to seeding rice through increasing their number at one pass of the tractor, and by using more herbicides. In other words, some or all of the operations such as cultivation, planing, seeding, applying fertilizers and herbicides and firming the soil are now performed at one pass.

Minimum tillage has been found successful in relatively clean fields and for soils which are in good physical condition. The land is leveled 3 to 5 days before seeding rice with scrapers or long-base land planers, then fertilized and harrowed with a rotary or disk harrow to cover the fertilizer at 10 cm depth, then floated and firmed, separately or at one pass. Field experiments with minimum tillage at two commercial rice farms in the Kuban delta riceland gave 6.34 t/ha of rice on one farm, and 5.3 t/ha, on the other, as compared with 5.74 and 4.43 t/ha, on the control fields, respectively.

A rotary cultivator-seeder, rotary cultivator-subsoiler, some types of integral and rotary plows may be successfully used for minimum tillage operations.

Long-time field test conducted on a commercial farm has proved the rotary cultivator-seeder satisfactory for cultivating soil, leveling microrelief irregularities, placing seed and covering fertilizer and firming soil thereafter, all for one pass. The rice stand density at harvest was 5 percent higher over the control treatment (traditional land preparation practice adopted on the farm). This increased yield by 7 percent, which averagely accounted for 6.3 t/ha.

Fertilization

The yield of a crop depends basically on a constant supply of essential nutrients from the soil although high levels of production are seldom possible without the application of commercial fertilizers. Practically, all rice areas require additions of mineral fertilizers for economical yields. Knowledge of previous cropping history and a soil test are useful in determining the amount and kind of fertilizer to use on rice. Specific fertilizer recommendations may vary between rice areas and even from farm to farm in the same area. Rice variety, water management, methods of weed control and other managerial variables affect the use of fertilizers. Various chemical soil and plant testing methods are used to determine the fertilizer requirement of rice and rice soils. The results of tests can be in-

terpreted with reasonable accuracy if basic information on the complex chemical changes known to occur under submergence is available. Any information on a flooded soil condition is of value in determining the fertilizer requirements for rice.

The requirement of plants for nutrients during part or all of the growing period can be determined by the nutrient concentrations in the grain yield which, usually, include very many chemical substances. Of these, nitrogen, phosphorus, potassium, calcium, iron, sulfur and magnesium are most essential. In addition, sufficient amounts of micronutrients or trace elements, such as boron, molybdenum, copper, zinc, manganese, cobalt, etc. are necessary for the formation of a good yield. The soils for rice should have essential nutrients in amounts sufficient for the formation of yield and in forms available to the plant.

As is evident from Table 6, the uptake of the essential nutrients from the soil by rice is smaller than by other cereals and row-crops (sugar beet and potato) and is still lower than by cotton, grown also under irrigation. It should be noted, however, that the uptake of nutrients from the soil depends on rice variety, yield, conditions of growth, and rice acreage. K. S. Kirichenko [5] reported concentration in rice of essential soil nutrients, calculated per 100 kg of grain and straw: 2.42 kg N; 1.24 kg P; 3.15 kg K, for the Kuban rice-growing areas. This can be compared with 2.35, 0.98, and 3.1 kg, respectively, for the far-eastern rice belt, reported by B. A. Neunylov [6]. Besides, the amount of nutrients removed by plants from the soil depends on stand density, rate and depth of fertilizer application, and the environmental conditions pertinent to the rice locality.

Only part of mineral nutrients is utilized by the plant, a lot more are simply lost by leaching (infiltration, drainage and leakage waters). Nitrogen fertilizers may be lost through nitrification and subsequent denitrification, or volatization, depending on the source of the element. Mineral deficiency of the soil due to losses as well as its productivity can be corrected by additions of commercial fertilizers.

Nutrition problems, however, cannot be regarded separately from the entire system of crop farming. They are directly related to other factors of plant life, such as heat, water, daylight, response of environment, etc. In that respect, the lack of nutrients due to various losses can also be made up for through rotations, proper land preparation, weed control, growing manurial crops, etc. Fertilizer application remains, however, essential for improving the nutrition of rice crop.

Proper rotational applications of fertilizer, both organic and mineral or commercial, are a key to high grain yields.

Table 6. Uptake of Soil Nutrients by Selected Crops

Crop	Yield, t/ha	Nutrients restricted in yield, kg/ha		
		N	P_2O_5	K_2O
Rice	50	120-125	50-62	120-150
Cereals	25-30	85-100	30-40	60-90
Grain corn	75	160	75	210
Silage corn	500	150	60	120
Potato	250	125	50	230
Sugar beet	500	250	80	400
Cotton	30	160	50	160

Mineral Nutrients and Sources

Using the oxidation-reduction status of soil as a basis, we divide, conditionally, the growing period into two stages, the "vegetative" and the "generative". The period up to full emergence will be the vegetative stage, and that from tiller formation to fertilization of the ovary, the generative stage. The beginning of the latter stage is marked with vigorous root growth which tends to gradually stabilize by the time when the vegetative apex starts to differentiate. Each of these stages is characterized by different physiological processes. Oxidizing conditions in the soil prevail during the first stage of the growing period, and the reducing conditions during the second. Nutrient requirements of the rice plant during these two stages are therefore different.

The uptake of nitrogen, phosphorus and potassium by the rice plant is highest from the four-leaf stage to tube-formation; it is less high in flowering, and is still less high in ripening. By tiller initiation, the uptake by rice of nitrogen is almost 10 percent, and that of phosphorus, 6-7 percent of the total plant requirement for these two essentials. About 90 percent of the required nitrogen and potassium are utilized by the plant at panicle formation and only 10 percent of these nutrients are used from blooming to the dough-grain stage. The plant uses almost all of the required phosphorus from tillering to blooming. Tests and practical experience have indicated that proper uses of commercial fertilizers on rice are the preplanting and postemergence applications, i.e. at tiller unitiation.

Sufficient supplies of nutrients through application of commercial fertilizers are essential at the beginning of plant growth. They are required to obtain rice plants with strong culms, long leaves and productive panicles. Such plants will develop more leaf chlorophyll and protein, be more viable and active photosynthetically, and produce more tillers at earlier dates of development.

Nitrogen is an essential nutrient for rice. Usually ricelands are deficient in this element to maintain high levels of rice production. By rough estimates, about 95 percent of riceland need additions of nitrogen in the form of mineral fertilizer for economical yields. A weak straw due to underdeveloped sclerenchyma is typical for rice plants grown in rice soil with excess nitrogen. Such straw lignifies poorly, and is therefore susceptible to lodging. Leaf yellowing, poor growth, small leaf area, thinning of the rice culm are usual symptoms of nitrogen deficiency in the rice soil.

Rice responds readily to nitrogen fertilizers which, for this and other reasons, are the most important in rice fertilization programs. The sources or forms of nitrogen for rice vary widely, and are applied differently. Ammonium and amide forms of nitrogen are generally preferred to nitrate forms because nitrates are difficult to maintain in a flooded rice soil. Ammonium fertilizers, such as ammonium sulfate, ammonium chloride, anhydrous ammonia, ammonia water, composite ammonia-containing materials, and amide materials, such as urea or carbamide, calcium cyanamide, are preferable because they reduce more to soluble ammonium nitrogen, and are about equal in efficiency.

Nitrogen fertilizers in which part of nitrogen is in nitrate form (e.g., ammonium nitrate) can be applied as a topdressing (at tillering) on rice soon after the reducing zones have formed on the soil surface and in the root zone. But even in such cases, a considerable amount of nitrogen applied may be lost. The major reason for different availability of various forms of nitrogen to the plant is poor retention in a submerged rice soil.

Experiments at the USSR Rice Research Institute to compare nitrogen fertilizers indicated that, the three year average rice yield in the control treatment (zero nitrogen) was 4.06 t/ha; yield increment with 60 kg/ha P_2O_5 applied as basal fertilizer for treatments with ammonium sulfate was 1.58 t/ha; with ammonium chloride 1.58 t/ha; with urea 1.54 t/ha; with calcium cyanamide 1.25 t/ha; and with ammonium nitrate 1.03 t/ha. Ammonium sulfate, ammonium chloride and urea proved most efficient. Urea, a high-analysis fertilizer, proved good for post-emergence topdressing.

Phosphorus. Prosphorus is another essential nutrient for rice. Application of phosphorus fertilizers on the rice fields benefits the rice grower through increasing the grain yield. An essential constituent in some

Table 7. Yield of Rice as Related to Sources of Phosphorus

Source of phosphorus	Yield	
	t/ha	%
Control treatment (no P)	5.10	100.0
Superphosphate, powdered	5.41	106.0
Superphosphate, fluor-free	5.13	100.3
Superphosphate, from apatite	4.97	97.4
Thomas (slag) phosphate	4.88	95.7
Phosphorite meal	4.31	84.5
Dicalcium phosphate ($CaHPO_4 \cdot 2H_2O$)	5.04	99.0

organic compounds phosphorus plays an important part in the metabolic exchange. Its deficiency, therefore, affects severely growth and development of the rice plant, particularly at the initial stages. Rice is well supplied with this nutrient even on the soils which include almost insoluble forms of phosphorus. This can be explained by the fact that flooding a soil often provides conditions for the increased availability of the native phosphorus. Factors that appear to associate with the increased availability include pH modification and reduction of insoluble ferric phosphorus to its more soluble ferrous forms.

Of the phosphorus fertilizers, all forms of phosphate are good for rice, superphosphate being superior and therefore preferred to phosphorite meal and dicalcium phosphate. The tests have shown that some sources of phosphorus may even reduce yield.

As is clear from Table 7, the yield increased in the treatment with superphosphate. Some fertilizers were satisfactory, others produced no results, and phosphorite meal was inferior to all others. In the tests, phosphorite meal proved satisfactory only on acid soils.

Rice yields on some soils are better when phosphorus is included with nitrogen. In some years, when phosphorus is needed, the added growth and yield often require that additional nitrogen be supplied. Where rice produces better growth, nitrogen rates should be increased. The nitrogen-phosphorus ratio at which the yield increments are largest depends on rice acreage, soil type, forecrop, variety, time of seeding, etc. Single phosphorus fertilizers can be applied to the plowed grassland and green

manured fields, or to new lands rich in organic matter. Even where nitrogen content seems sufficient, supplemental post-emergence applications may prove profitable.

Potassium is a useful element in its benefits to the crop. Potassium deficiency reduces root and top development of the rice plant; its susceptibility to diseases and lodging becomes particularly pronounced. Normally, soils contain sufficient potassium to satisfy rice requirement. One has to remember, however, the enhanced uptake of potassium by rice growth. For this matter, increased availability of the element in the soil is most desirable for the rice crop.

Potassium salt containing from 30 to 40 percent K_2O, or potassium chloride with 55 to 60 percent K_2O are the most common sources of potassium. Potassium chloride is preferred mostly in saline soils. No response to single potassium applications has been noticed for most ricelands which is explained by sufficient concentrations of the element in most rice soils, and in floodwater. Potassium proved effective in increasing the resistance of rice to lodging where nitrogen and phosphorus are used and the levels of production are high (more than 5 t/ha).

Compound, concentrated fertilizers (phosphorus-ammonia and complete fertilizers, ammophos and ammophoska) are beneficial for rice. The proportion of the nutrient elements in such fertilizers is important for the rice plant, and can be corrected, if required, by applications of single fertilizers.

Micronutrient deficiencies. Beside the essential elements, such as nitrogen, phosphorus and potassium, rice needs micronutrients (boron, copper, zinc, cobalt, vanadium, and other trace elements). But iron and manganese are most important for rice.

Iron deficiency may be corrected by spreading farmyard manure, turning under green manure crops, and by planting perennial grasses in the rotation. Manganese deficiency of soils is corrected by the application of manure and manganese fertilizers, such as manganese slag, manganese sulfide, manganese superphosphate, etc., and by the preplanting treatment of seed rice with manganese. The absence or lack of certain micronutrients in the soil, unbalanced proportions of micronutrients to essential nutrients reduce the efficiency of commercial fertilizers. The effect of trace elements depends basically on their availability to the plants, source and physical condition of the fertilizer, and on soil type and climatic conditions. The requirement for micronutrients is determined by a soil test.

Experiments on preplanting seed dusting with trace elements have been conducted recently in the south Ukraine (the Ukrainian Rice Field Sta-

tion). The test compared the effect of sulfides of manganese, magnesium, iron (oxides), copper, cobalt, also of potassium iodate and ammonium molybdate (talc) powdering served as the control treatment. Generally seed treatment increased root and top development and improved yield. Yield gain per hectare of rice in treatments with copper, cobalt, iron and magnesium sulfides, and with ammonium molybdate was 0.51 to 0.62 tons.

Micronutrients benefit rice quality. Thus, the grain starch content in the test increased by 1.9-6.6 percent, and grain protein content, by 0.33-1.31 percent, as compared with the controls. The starch content in the grain and total starch yield per hectare were highest when the seed was dusted with molybdenum, copper and cobalt. The protein content was highest when the seed was dusted with magnesium, iron, copper, cobalt, and molybdenum.

The preplanting seed treatment with micronutrients has proved an effective and economical practice to increase yield and to improve grain quality. The operation is done at the same time with the presowing seed dressing and involves no additional expenses or equipment.

Organic Matter and Sources

Turning under the stubble and other plant debris behind rotational crops and applying the organic (manurial) fertilizers is a suitable practice to replenish the organic matter content in rice soils. The practice improves biological activity, texture and physical condition of soil, increases mobilization of available nutrients, and provides an oxidation-reduction status favorable to rice. Organic matter is important as a source of energy for soil-borne useful microflora, and as a material to form valuable humic substances. Organic matter improves greatly the soil-water agronomic factors associated with rice production.

Farmyard manure, composts, green manure leguminous crops and chopped straw are good sources for replenishing rice soil organic matter. Other sources are root residue and regrowth of rice after the field is drained. The periodic incorporation of manurial sources into the soil are thus desirable. The best conditions for rice production occur however when the soil supplies of organic matter are replenished once after two successive crops of rice.

Farmyard manure is the most valuable form of organic matter for rice crop. It supplies the soil with both the essential nutrients and the micronutrients, such as boron, manganese, zinc, cobalt, sulfur, iron and

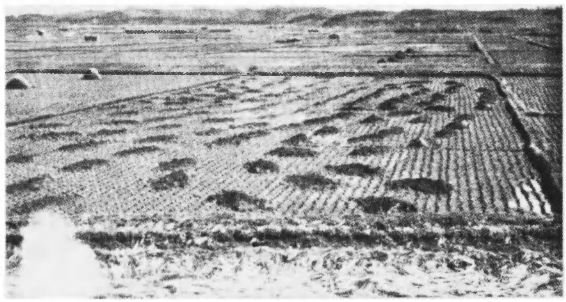


Fig. 28. Rotted manure scattered on rice field

many others. In addition, it brings into soil large amounts of microorganisms which help decompose organic matter both in the manure applied and in the soil, and convert it to the plant-usable forms. Farmyard manure contains various growth stimulants, i.e. substances, such as auxins, heteroauxins, gibberellin, etc., which stimulate plant root and top development. Incorporation of farmyard manure and other forms of manurial fertilizers improves considerably the physical and biological soil properties in the plow-line layer by loosening heavy clay soils and rendering more coherent sandy soils.

Rotted manure has been recognized as a good source of organic matter for rice soils. In all manurial treatments it is desirable that rotted manure be spread as uniformly as possible over the rice field to avoid a nonuniform distribution of nutrients in the soil. This will provide equal conditions for plant development during growing season and eliminate the danger of outbursts of *Piriculariosis* (rice blast).

The usual time to spread manure is after harvest before fail plowing, or early in the spring before the field is replowed for seedbed preparation (Fig. 28). Rates of application may vary from 20 to 40 t/ha depending on soil fertility levels and its organic matter content.

Where the topsoil has been removed as the result of land forming and surface smoothing operations, the rates of manure application are highest. Places of bare ground need up to 80-120 t/ha manure to make up for soil infertility, increase humification and avail plants of sufficient

nutrients for at least first couple of years. Field practice has shown that proper fertilization of the soil in checks (undergone basic land forming) with manure and commercial complete fertilizers makes possible obtaining yields over 6 t/ha.

The method of mulching soil with chopped straw and its effect on rice yield has been tested recently at the USSR RRI and in the Kuban rice areas. The method provides for fine mincing of straw as it leaves the harvester in a chopper during the second round of threshing rice grain from windrows, and a uniform distribution of chopped straw throughout the check surface. The straw is then turned under to a 12 cm depth by working the field over with a rotary or disk harrow, or with a disk or bottom plow. Before seeding rice, 8 to 10 kg nitrogen (active ingredient) are applied to each ton of chopped straw turned under. The USSR RRI tests have proved the rice straw an effective source of organic matter for ricelands, which gave a stable rice increment of 0.8 t/ha, with 120-180 kg N plus 90 kg P_2O_5 per hectare being applied as basal fertilizer. The method has been recommended for a pilot production in all rice-growing areas of the country with the technique of spreading straw being adapted in each rice farm separately.

Green manure crops. Another reliable source of organic matter is leguminous green manure crops plowed down to improve soil productivity. Increased rice yields may result from plowing down such green manures as the fall-sown peas, vetch, and soybeans, in the Far East. Field peas and vetch are common use in ricelands for the winter-grown cover crops and green manures. Being a dryland crop, field peas are usually grown in checks lying at highest elevation of the rice system to avoid damage from inundation and waterlogging. The plant is sufficiently cold-resistant, and can germinate at 1-2°C. By the time of sowing rice in the spring, the late October plantings of field-peas produce up to 30 t/ha of growth which is equivalent to 30 kg actual nitrogen. But more nitrogen may be needed for economical rice production. The highest yields are obtained when rice follows peas that are turned under as green manure, with optimum rates of actual nitrogen and elevated rates of superphosphates (120 kg/ha P_2O_5) being applied additionally. The use of green manure crops in ricelands gives 1.2-1.4 t/ha more rice provided the crop growth is high and the soil is given adequate treatment. The highest effect is however achieved with the addition of mineral fertilizers. All green manures which supply considerable nitrogen should be plowed down as near to seeding time as possible (5-10 days before) to avoid premature mineralization of nitrogen and accumulation of nitrates which are likely to be lost after a flood is applied.

Turning under the aftermath in grassland and the regrowth of other rotational crops just ahead of rice for manurial purposes is also beneficial. Turning under alfalfa in the spring before sowing rice by multiple disking or working the field over with a rotary plow or a cultivator is more advantageous than plowing down grasses in the fall.

Cover crop. Returns to the rice grower are high with cover crops used in ricelands for green manure and green chop. The above-ground part of the crop provides nutritious forage for livestock, and the stubble and root debris, sufficient organic matter for the soil. Turning under plant residue for rice following a cover crop with the additional 120 kg/ha N and 90 kg/ha P_2O_5 applied as a basal fertilizer usually gives 2 t/ha more rice. A mixture of peas and winter wheat is a common cover crop in the Kuban area. The top growth is fed to animals, and the stubble is turned under for rice. With an average yield of 6.5-6.8 t/ha, this practice ensures additional 0.35-0.4 t/ha of rice. Where green manures are used to supply soil with new organic matter, the efficiency of commercial fertilizers is high. It is advisable therefore to correct the rates and proportion of mineral fertilizers with respect to the amount and kind of organic matter turned under. Where the aftermath or a green manure crop has been used as a source of new organic matter, commercial nitrogen is reduced, and phosphorus and potassium rates are increased.

Soil Liming

Rice easily adapts itself to a variety of soil reactions. Flooded soils exhibit a tendency to adjust to a pH approaching neutrality. Although a pH of 6.5 is regarded as the optimum soil reaction for rice, the plant produces rather high yields at soil pH ranging between 5 and 8.5 (moderately acid to slightly alkaline). It is very rare that the need may arise to modify a soil reaction for the rice plant. Additions of limestone are not necessary for rice grown on moderately to slightly acid (pH 5.0 to 6.5) soil. Besides, such soil reaction is favorable for the immobilization of nutrients, grass vegetation and for other crops accompanying rice in rotations. Good effects on rice yields have been noted only from adding lime on strongly acid soils, and only during the first years after application. This is explained by improved supplies to the plants of nitrogen and phosphorus. It has been observed that the best results from lime applications are obtainable where acid soils have been recently replenished with organic matter. It is feasible to lime acid soils twice in rotation by using a multi-row drill or a broadcast distributor at rates from 0.8 to 1.2 t/ha before seeding grasses,

and in the spring near the time of seeding second-year rice following rice rotated with grasses. Like in fertilization programs the uniform distribution of limestone is desirable to increase the efficiency of lime in decomposing organic matter, modifying the soil reaction, and inducing "forced" immobilization of plant-borne nutrients in the soil.

In the far-eastern rice belt, the new lands developed for rice are often excessively acid and adding small amounts of lime has been found beneficial for the rice crop. Liming recommendation for acid soil (pH, from 4.1 to 4.2) includes two additions per rotation of 800 to 1 200 kg/ha lime for grasses and one addition at the same rates for rice sown the first year after grasses. Liming soil for rice (800 kg/ha) in a field experiment increased yield by 0.77 t/ha.

Additions of lime have been beneficial in the Kuban rice area in localities where soils are subject to gradual waterlogging. On a limed soil rice produced 0.71 t/ha more grain than rice on the field without added limestone.

Fertilization Practices

The real worth of fertilizers becomes apparent with improved land preparation, irrigation and drainage facilities, varieties suitable for mechanization, and proper use of airplane and ground equipment for applying fertilizers. Benefits to the grower may increase from proper handling, storage and preparation of fertilizers, and a proper choice of method of fertilizer application.

Preparation includes grinding the fertilizer with a mixer-loader, and screening with a mesh size not more than 3 × 3 cm. Weighted amounts of the ready-to-apply fertilizer are then handled to the field side for application.

It is preferable that nitrogen and phosphorus fertilizers be applied separately with a drill-type distributor for even spreading over the field before seeding rice. Various other ground equipment such as top-feed fertilizer spreader (Fig. 29) and trailed hopper-type distributors may also be used to apply fertilizers. Cross-plot fertilizing with these distributors is desirable to overcome irregularities of distribution. Organic manures are distributed with manure spreaders and with various other types of manure swath-makers.

Although the fertilizer is usually distributed with a tractor-drawn ground-driven implement, it may be distributed by airplane. A fairly good distribution by airplane is possible with well-designed equipment and a few precautions followed. Characteristic deposit patterns have to be

Fig. 29. A tractor-drawn bulk-fertilizer applicator

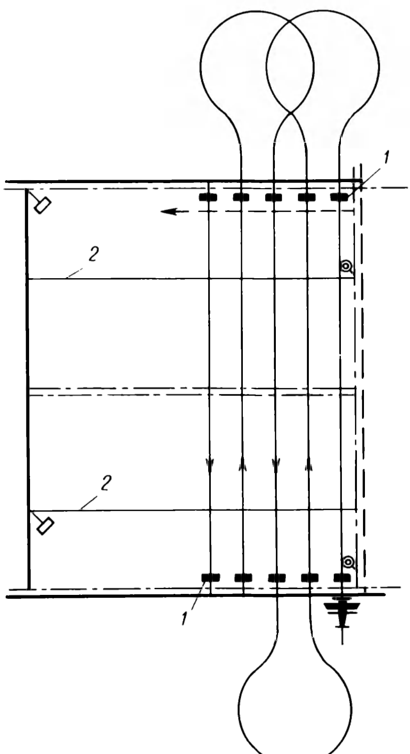


Fig. 30. Distributing fertilizer by airplane

1 — flagman, *2* — cross levee

determined for the type of the airplane distributor used. From these patterns, optimum flagging intervals are determined to allow for an overlap enough to ensure a uniform application. A ground personnel is necessary

to maintain the proper overlapping of swaths. A flagman should be stationed at each end of the field to pace the necessary flagging interval or distance. It is necessary that the flagging interval be measured correctly and that the cropplane fly directly over the two flags (Fig. 30). It is possible to mark the flagging distances or intervals with stakes or flags so that the flagman will not need to pace the distance.

Rate, time, and method of application. The rates of fertilization and the proportion of nutrients in a fertilizer applied depend on the rice acreage, plane requirements for nutrients, availability of these in the soil, rice variety, crop that precedes rice in rotation, and the anticipated level of rice production. More exactly, the rates of fertilizer application are determined by field experiments, use of chemical soil and plant analyses, and calculation methods which permit taking into account the uptake of nutrients by the plants, content of available nutrients in the soil and their various losses. Beside losses and amounts of usable nutrients, allowance should be made also for deficiencies of the soil in particular nutrient elements, probability of their losses, and of efficient use of a nutrient element by the plant from various fertilizer sources.

The additions of nitrogen should be higher than its losses and quantities efficiently used by rice. Rates of phosphorus should be increased due to a small coefficient of its assimilation from the fertilizer. The rates of potash are usually 1.5 to 3 times smaller than its total uptake and loss from the soil because of the high rate of assimilation of the nutrient from the potassium sources applied, and of its sufficient content in the soil, and in floodwater.

Optimum rates of fertilizer applications and the N-P-K ratio are specified on the basis of soil tests, plant analyses and empirical data and are varied from area to area depending on the soil type, forecrop, and variety.

Table 8 gives approximate rates of fertilizers used in two large rice-growing areas of the country. These rates may vary from place to place in one area or even within one locality. The timing and uniformity of fertilizer applications are very important. Depending on the time of fertilization, the fertilizers may be used as *single* or *basal* (applied before seeding), *supplemental* (applied at seeding), and *topdressing* applications (applied at any phase of plant life, as may be necessary).

Timing for nitrogen applications is very essential. It is preferred to apply total nitrogen as a basal single application as near (2-3 days) to seeding time as possible. Because nitrification is rapid in a wet soil (before a flood is applied), almost all nitrates are lost after flooding through leaching and subsequent denitrification. Single applications of increased rates of nitrogen (over 90 kg/ha N) are not practical and, therefore, 60 percent of total nitrogen amount is applied as basal and the remaining 40 percent, as topdressing fertilizer.

Table 8. Guide to Rates* of Commercial Fertilizers (basal + topdressings), kg/ha

Rice area and soils	Nutrient element	Rice following alfalfa or clover, years				Rice following green manured fallow, years			Rice following grain crop grown in seeded fallows			Rice 4 years and more
		1	2	3	4	1	2	3	1	2	3	
The Northern Caucasus;	N	60-90	90-120	120-150	150-180	60-90	90-120	120-150	90-120	120-150	150-180	150-210
black and	P	60-90	60-90	90-120	90-120	60-90	60-90	90-120	60-90	90-120	90-120	90-150
meadow-boggy	K	45-60	60-90	60-90	90-120	60-90	60-90	60-90	60-90	60-90	60-120	90-120
The Far East;	N	30-60	45-90	60-100	80-110	30-75	60-90	80-110	60-90	70-100	80-110	90-110
meadow-	P	45-60	45-60	60-90	60-90	45-60	60-90	60-90	45-60	60-90	60-90	60-90
podsolic-gleye	K	45-90	45-90	60-120	75-120	60-90	60-90	75-120	60-90	60-100	75-120	75-120

* Calculated on active substance basis.

Topdressings may be timed differently depending on how the conditions progress for nitrogen immobilization within the soil, and on the rate of growth of the rice plant. The need to topdress arises mostly at emergence and tiller formation. Where the requirements of rice for nitrogen are high, two topdressings during each of the above stages of plant growth are applied, although a third operation may sometimes be required. Where little nitrogen is needed, one topdressing will be sufficient. With all tillers formed, rice benefits little from nitrogen applied as a topdressing, and such applications become unnecessary because excess nitrogen causes undesirable growth and delays maturity. The use of nitrogen fertilizers applied late in the growing season as topdressings may however be beneficial only in the southernmost areas sown mostly to late-season varieties of rice.

The practice of *split application* of nitrogen fertilizers relies not only on the physiology of the rice plant. It also takes into account various transformations nitrogen is subject to in a flooded soil, the dynamics of its available forms, and also its losses due to leaching and denitrification.

Large-scale tests have shown different effect from single and split applications of nitrogen fertilizers depending on rice-growing area and conditions of growing. N. N. Smirnova and E. P. Aleshin [7] (the USSR RRI) reported the results of such tests conducted in the Kuban rice-growing area. The yield with total nitrogen applied to rice as basal was 5.47 t/ha. The yield increment where total nitrogen was split into basal and topdressings that were applied at seedling establishment was 0.34 t/ha; during emergence and tillering, 0.14 t/ha; during emergence, tillering, and tube initiation, 0.29 t/ha. The yield increment with total nitrogen applied only by topdressing rice after emergence accounted for 0.51 t/ha, but where total nitrogen was topdressed during emergence and tillering, rice produced 0.17 t/ha less yield than rice with total nitrogen applied as basal.

In similar trials in the Lower Volga rice area, yield with a single application of total nitrogen as basal was 3.67 t/ha; increment from split applications applied during emergence was 0.74 t/ha; after emergence, tiller formation and tube initiation, 0.94 t/ha.

Emergence and tillering are the commonly adopted dates for applying nitrogen in all rice-growing areas of the European USSR. Using nitrogen in split or divided applications increases not only the grain yield but improves also grain quality through increasing its protein content. The method produced little or no effect on the grain starch content which usually remains unchanged, or may slightly decrease.

The additions of 120 to 150 kg/ha of actual nitrogen have been found beneficial and optimum for high yields per hectare on the Kuban rice

fields. Higher rates caused bad lodging of plants, outburst of blast, and impaired yield per hectare.

Field tests and practical rice farming have evidenced that applying fertilizers by drilling is superior to broadcasting. Nitrogen drilled at rates[1] 60 and 120 kg/ha produced 1.5 t/ha more rice than the same rates of broadcast nitrogen. This also increased the amount of crude protein in the rice grain.

Usually, phosphorus and potassium are applied as a basal fertilizer 8 to 10 days before seeding rice. There is little or no effect from these two fertilizers applied in the fall. Part of total phosphorus and potassium applied as a topdressing adds, in most cases, very little to the grain yield than when total phosphorus and potassium are applied as a basal fertilizer. The real worth of phosphorus increases only where its deficiency symptoms in young rice plants (narrower leaf-blades turn erect, slightly discolored and dried up at tips) become apparent. The situation can be corrected by topdressing rice with phosphorus applied between emergence and the end of tiller formation. Superphosphate, widely used on rice, is most effective when applied singly preparatory to seeding rice.

Many field tests have proved that late and mid-season topdressings with potassium do not pay although increase the yield slightly.

Recent RRI recommendations have been to apply on the maturing rice minor quantities of phosphorus together with stimulating substances (2-4 D) as a side-dressing after blooming to hasten the filling and accelerate the drying of grain for harvest. Phosphorus fertilizers are efficient on rice only when used with nitrogen, while the potassium fertilizers, when included with nitrogen and phosphorus. In new lands where soils are in rice just shortly, additions of potassium fertilizers fail to produce economical increments. The Soviet and foreign studies as well as practical field observations have shown that nitrogen fertilizers used in rice rotations pay fairly well only when placed at 10-15 cm depth by a drill-type distributor (Fig. 31), but not broadcast on the soil surface. The use of scrapers or land-planers following such a fertilizer distributor should be avoided to prevent irregularities of fertilizer distribution. Phosphorus and potassium materials are usually covered at 12-20 cm depth during soil loosening or retilling with a chisel-type cultivator.

Field studies at the Uzbek SSR Rice Research Institute proved deep drilling of complete fertilizers (N, P, K) to depths from 10 to 12 cm more effective than shallow coverage of fertilizers near seeding time. The practice of applying low rates of nitrogen-phosphorus fertilizers during

---

[1] As active substance.

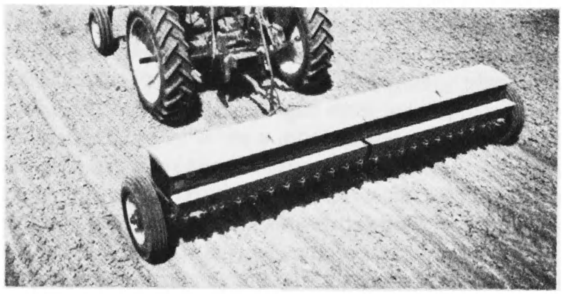


Fig. 31. A ground-driven row-type fertilizer distributor

seeding rice with a multi-row drill-type distributor also seems suitable. Drilling of seed simultaneously with a double superphosphate-urea mixture placed to not less than 2-2.5 cm deep has given satisfactory results. Shallower placing of such mixtures may cause injuries to rice plants and bad thinning of stand. Proper application of fertilizers during seeding provides good nutritive conditions for plants during seedling establishment and saves a topdressing at this stage of plant development.

Supplemental fertilization and topdressings require that the depth of water in the rice fields be as low as possible to avoid losses. Complete drawdown or continuous inflow and outflow of water are inadmissible. The water is maintained until all nutrients fully recede into the soil with floodwater.

Proper fertilization programs are important for a successful rice culture. In rice rotations, fertilization of fields should be varied following the adopted patterns of cropping, and the rates should be adjusted to soil fertility levels each season depending on rotational crops, soil cultivation methods and processes occurring in the soil.

Unreasonably high rates of mineral fertilizers, and of nitrogen in particular, impair grain quality. The amount of nitrogen in the grain increases, and that of phosphorus decreases. This renders the grain less vitreous, reduces its absolute mass and lowers grain yield per hectare.

Field tests and practical farming have shown that productivity of the rice plants following grasses (alfalfa) to a large extent depends on the nutritive condition of the previous grass crop. Nitrogen is most essential for the first and second-year stands of alfalfa. Nitrogen increases the efficiency of phosphorus and potassium used on alfalfa, and facilitates growth. It is desirable that the rates of nitrogen included with potassium and phosphorus be a little higher than usual.

The field studies at the USSR RRI conducted in meadow blacksoil have shown that 120 kg/ha N, 90 kg/ha P_2O_5 and 45 kg/ha K_2O applied before seeding grass, and 30 kg/ha N, 60 kg/ha P_2O_5 and 45 kg/ha K_2O applied to the second-year grass stand as a topdressing produced 18.85 to 21.64 t/ha of hay, or 2.99 t/ha more hay than the control field.

Generalization of the results from a series of geographical experiments has revealed that optimum rates of complete mineral fertilizers on rice give from 1.5 to 2.5 t/ha more rice, or 40 to 80 percent more, than the control treatments with no fertilization. In 25 field tests conducted on rice soils of the Northern Caucasus, average yield of rice fertilized at optimum rates was 6.52 t/ha, average yield increment from the optimum fertilization accounted for 2.18 t/ha, or 50.2 percent. The returns to 1 kg active substance came to 10.4 kg of rice grain and was higher than the country's average. In the fertilizer experiments conducted in the Cis-Caspian riceland, the best results were obtained using complete fertilizers.

Fertilization programs should take into account biology of rice varieties adopted in the locality. The varietal response to fertilization may vary, and the USSR RRI maximum rates of nitrogen fertilizers, kg/ha as active substance, for selected varieties seem to be appropriate here:

Dubovsky.....................	129-150
Kuban 3.......................	90-100
Krasnodarsky 424...........	160-180

The chief factors that determine the fertilizer efficiency are:

(1) climatic conditions that include degreedays (sum of above-critical temperatures (+ 15°C) for the growing period), length of daylight, solar radiation;

(2) genetical and physical characteristics of soil that include organic matter content, available nutrients, temperature, texture, and cultivation history;

(3) biology of rice varieties that include yielding potential, maturity period, resistance to diseases and lodging, etc.;

(4) technical possibilities and management, i.e. availability of trained personnel, rice-farming machinery, required sources and quantities of fertilizers, proper timing for fertilizer applications and other field operations.

The returns for the rice grower from commercial fertilizers used may be increased through proper storage, handling and application, improved agronomic practices and equipment, and a few precautions to follow.

Seed and Seeding

Planting or seeding is an important operation in crop farming. The choice of seed, time and a suitable method of seeding is essential for the

future crop. At seeding, seeds are placed on a seedbed at a desired depth and an interval to provide each plant with an area of nutrition. Good results can be obtained only when a crop is seeded or planted on a good seedbed by a suitable method, at a proper date, optimum rate and covered at an adequate depth.

The yielding ability of individual plants and, hence, yield of crop per unit area, depends largely on the environmental conditions and how these will develop during the rest of the growing period.

Added growth and yield of each plant sown require that an area around its root system called the plant area be sufficiently large to make an efficient use of essential soil nutrients.

The provision of an optimum plant area for each individual plant is extremely important for a high level of production. This can be achieved only through a timely and expertly executed seeding operation. The statement equally applies to rice culture.

Classification of Seed

High levels of production require that growers choose a locally well-adapted variety (or varieties) established as commercial, or registered as superior whose seed is released and distributed in required quantities to provide good-quality rice of different types for the market.

Proper choice of variety makes it expedient to choose a seed lot increased from a good source of foundation seed that is free from varietal mixtures or broken grains that does not contain red rice and weed seed, and has a high percentage of viable seed.

The seed of the first increase and the following reproductions falls into three categories: I (super-elite); II (elite); and III (certified seed), all different in standards for varietal purity and red rice content.

Categories of Seed

	I	II	III
Pure seed, %, minimum...........	99.5	98.0	95.0
Red rice, %, maximum.............	0.1	0.3	1.0

Certified seed can be of three classes (1, 2, 3) each distinct for its varietal purity, broken grain, viability standards, and other characteristics that are important for a good-quality seed material.

	1	*2*	*3*
Pure seed, %, minimum	99.0	98.0	97.0
Weed seeds, grains/kg, maximum	5	40	100
Germination, %, minimum	95	90	85
Moisture content, %, maximum	14	14	14
Moisture content, %, for the Far East, maximum	15	15	15
Broken grains within pure seed, wt. %, maximum	1	2	3

The seed Class 1 is characterized by rapid germination (100 percent in a germinator, and 60 percent in a field germination test), and a high seedling vigor. Seed in Class 3 is inferior and usually gives a 15 percent reduction in grain yield, increases seeding rate, and production cost.

Pre-Plant Treatment of Seed

The operation includes cleaning, grading, and treating seed with chemicals (desinfectants) for safe storage and better field germination. The procedure requires specialized equipment, such as a seed cleaner and grader, and a seed treater. All seed need to be completely processed including thorough cleaning, drying and treating. The seed is sometimes pregerminated by soaking.

A method for treating seed with ammonium sulfate and consequent air drying has been found suitable to stimulate germination. The technique implies that the cleaned seed put in mesh-bottomed baskets be dipped in a 30-percent solution of ammonium sulfate contained in specialized tanks, and be thoroughly paddled to bring the small-sized, poorly filled and empty seed, and trash to the surface from which it is scooped out. Following this procedure, the good seed is dipped a second time in a 42-percent ammonium sulfate solution, then removed and spread out in a thin bed on the ground to dry out, in the shade. Tests at the Kazakh SSR Rice Institute have indicated that natural aerating of seed in the open increases germination by 17 percent and treating seed with ammonium sulfate, by 15 percent.

Dressing seed with granosan M and treating it with ammonium molybdate have been also found stimulative. A semi-dry (slurry) method of dressing seed with colored granosan M is applied to the seed lot 3 to 4 weaks before seeding rice using a solution of 1.5-2.0 kg active substance to 8-10 l of water per ton of cleaned seed. Ammonium molybdate can be

included with a basal fertilizer at 1.5 kg active substance per hectare and buried to a depth of 3 cm.

The slurry method requires a solution of 30-50 g ammonium molybdate (active substance) to 40 l of water per ton of cleaned seed.

Rate of Seeding

Seeding rates should be selected so as to establish a stand density at which every plant enjoys an optimum plant area for making an efficient use of soil nutrients. This gives the highest average yield from the whole plant population in the rice field. Factors that determine a proper rate of seeding include biology of rice variety, seed size and quality, viability to germinate rapidly and establish seedling quickly, condition of the seedbed, soil natural fertility, anticipated fertilizer practices, date and method of seeding, and weather conditions. The rate of seeding therefore varies from one area to another, and in different parts within the same area. The rates of seeding are high where seed is drilled by the cross, cross-diagonal, and close-row methods. Seeding rates are minimum where seed is planted in wide rows to provide a larger plant area or where thin stands are desirable. The wide-row method of planting rice is suitably used in the seed industry for the rapid increase of the seed of superior varieties.

In major rice-growing areas, seeding rates are varied from 200 to 250 kg or 6 to 7 million viable seeds per hectare. For most of the cultivated varieties of rice, excellent yields are obtained from a seeding rate that gives assured populations between 250 and 350 plants, or 400 and more productive tillers per sq m. The rate of seeding is normally increased by 10 and 20 percent where soaked and pregerminated seed is respectively used.

The optimum seeding rate in the Kuban rice area is 6 to 7 million viable seeds per hectare for deep-drilled seed rice regardless of rates of nitrogen fertilizers used. The rate is about similar for seed placed at a minimum depth of 1.5 to 2 cm. Where rice is broadcast by airplane, best yields have been obtained from a rate of 230 to 240 kg viable seeds per hectare.

In the Don and Lower Volga rice-producing areas, seeding rates are about the same, i.e. 6 to 7 million, or 200 to 250 kg viable seeds per hectare.

In the Far East (Primorye), optimum rates of seeding depend largely on the planting method, and are 6 to 7 million viable seeds per hectare for deep-buried rice, 6 to 6.5 million viable seeds per hectare for seed placed at a minimum depth, and 5.5 to 6 million viable seeds per hectare for rice broadcast with a ground-driven seeder, or by airplane.

Highest average yields per hectare of rice in the Central Asia have been obtained from a rate of 7 million viable seeds per hectare.

Seeding rates can be lowered where cultivation practices, such as land preparation, water management, use of disinfectants and planting methods, are good enough to aid germination by themselves. Where soil is fertile and is additionally fertilized, rice in extremely dense stands is most likely to lodge prematurely, and produces poor yield with the grain of inferior quality.

Research in rice culture has indicated that unreasonably high rates of seeding (sometimes used by growers) do not necessarily result in the proportionally increased germination and seedling numbers. Germination rate is determined largely by Class of seed and adopted agronomy, i.e. land and seedbed preparation methods.

As has been mentioned earlier, superior cultivation methods and optimum dates of seeding can make it desirable to reduce the seeding rate. But to achieve a high level of production with a lower rate of seeding it becomes most expedient to obtain an optimum ratio between the number of productive tillers (panicles) and the number of grains set in the panicle.

Method of Seeding

Rice seed may be sown with ground implements or from the air in two basic ways, namely, by broadcasting and by row-drilling.

Rice may be broadcast, and disked and harrowed to cover the seed in dry soil. It may also be broadcast by airplane in water.

With ground-driven implements and dry ground the row drilling method has been most popular with rice growers. Modified techniques of the method include several seed drilling patterns and are termed as close-row, wide-row, and cross and cross-diagonal or oblique drilling. As research and development in agriculture advance further, methods and implements for seeding rice and other grain crops continue to improve.

The choice of any of the above methods for seeding rice depends on the adopted system of farming, traditions, condition and class of seed, seedbed condition, water management practices, rate of seeding, and variety.

Row drilling has been popular in most rice-growing areas. Rice is drilled on 45 to 60 percent of the rice acreage in the Russian Federation. Tractor-drawn disk drills are used to seed rice in rows spaced 15 cm to a uniform depth of 1.5-2 cm. Because commercial-type drill seeders have a wide range of depth to put the seed, the desired depth can be attained by attaching a skid rest (reboard) to the disk boot of the seeder. A disadvantage of drilling by the method is the unsuitable plant area that appears as an elongated rectangle 15 cm long and only 1 cm wide or a bit broader,

depending on the rate of seeding. Crowdiness of plants in a row affects growth and development and impairs yield. Although it is customary by the method to drill seed along the field's longest side with no regard to daylight orientation, it is very much desirable to seed rice from north to south to avoid mutual shading of plants.

Various modifications in the method and seeding patterns made recently benefit growers with small but assured increases (0.5 to 0.7 t/ha) in average yields. The various merits and demerits of some can be summarized as follows.

Cross drilling implies that rice be seeded once with the seeder along the field, and a second time with the seeder across the field. The method changes the plant area to almost a square, minimizes mutual shading and plant competition, and provides for uniform maturity. But drilling rice for two passes by the drill over the same area, however, spreads out the time of seeding, requires additional labor and expense, and causes compaction of soil.

Cross-diagonal drilling is suitable to rectangular checks. The operation proceeds in much the same manner as is previously described, but in the diagonally opposite direction. The method reduces the length of idle run of the drill or seeder and the area of headland, and hence shortens the seeding time. It gives good results in average yields, minimizes additional labor and other expenses, and is thus preferred to the previously described method.

Cross-diagonal drilling is however undesirable on loose soils because the seed that is drilled during the first pass is forced deeper into the soil during the second pass of the drill-seeder. This will cause nonuniform emergence and poor, thinned stands. The situation can be improved by using the close-row drilling technique.

Close-row drilling provides for a more uniform distribution of seeds for one pass of the seeder by placing the seed in a row with a 2-cm interval. This improves greatly the shape of plant area, thus equalizing the conditions for growth and development of plants in the neighboring rows.

Wide-row drilling, common in seed industry, is suitable for increasing foundation seed of new, superior varieties, or certified seed material for the need of the commercial rice grower.

Seed broadcasting, the oldest method of sowing in the history of land cropping, has long been popular because it does not require much machinery. Rice, broadcast with any known implements (an endgate seeder or drill-seeder with disks removed) or by airplane, is distributed randomly over the field whose soil must be mellow, have good tilth to bury the seed uniformly. Rice that is broadcast lodges more than the drilled rice.

The seed is usually broadcast or drilled without previous germination,

though, sometimes, the seed may be germinated before sowing. The uniform coverage of such seed requires a suitably prepared seedbed with a smooth surface and fine tilth, and firming the soil with a roller behind the seeder.

On many large-scale rice production units the seed is broadcast from airplanes. Usually the airplane is used for seeding rice in water, but sometimes the aerial seeding can also be done on a wet ground (Fig. 32). The limiting factors of aerial seeding include weather condition, wind drift of seed, and losses by misplacing the seed material into the non-productive ground. The situations which defeat the purpose of ground implements are not infrequent in rice production and aerial seeding has thus become the usual practice. Cropplanes are advantageous during

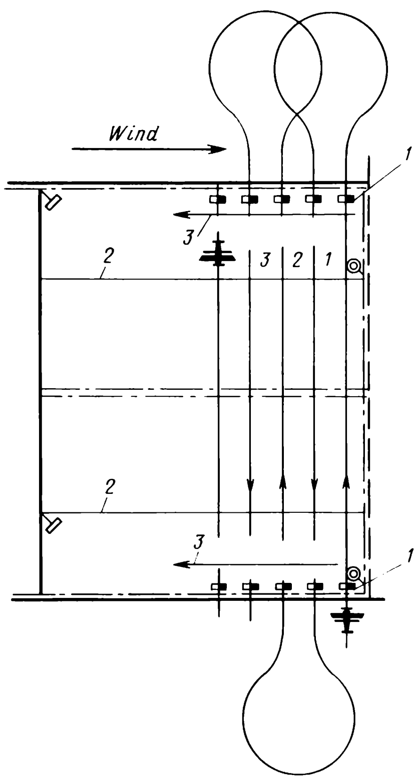


Fig. 32. Aerial seeding patterns
1 flagman, *2* cross levee, *3* direction for flagman to pace the interval distance

rainy weather and over the waterlogged lands where the ground machinery is useless. In such situations, soaked seed is broadcast from an airplane into checks flooded to a depth up to 10 cm. Good results have been obtained by seeding soaked seed into a sufficiently wet soil immediately after the flush-water has been removed to bring up rice and to follow with intermittent flushing until harvest. The soaked seed produces seedlings 3 to 5 days earlier and gives 0.5-0.8 t/ha more rice. The efficiency of aerial seeding is high (150-200 ha per workday). But because not all seeds are covered, the water-seeded rice is likely to lodge more than the ground-established crop. Seeding rice in water by airplane or helicopter has been common practice in the USA, France, Cuba, and some other countries. Aerial seeding has been found satisfactory in the Kuban rice-growing areas and in the Far East of this country. Good stands and yields have been obtained in the Kuban old delta ricelands from seeding rice in water, and on dry ground. In both cases, dry seed was broadcast from a helicopter with a rotary distributor. The helicopter with rotary distributor covered 30 ha per flying hour, or 150-200 ha per workday. The crop sown by this method was harvested earlier than usual.

Because helicopters have more freedom of manoeuvre than cropplanes, losses of seed material by seeding on nonproductive ground were minimized by making two trips across the field at a 5 m altitude following the canals and roads where 30 m wide strips of rice land have intentionally been left unseeded.

Time of Seeding

Usual time for sowing rice in the Soviet Union comes when the weather is warm enough for rice to germinate quickly and establish seedlings rapidly and uniformly. Seeding time can be influenced, directly or indirectly, by weather during land and seedbed preparation, method of seeding, cold tolerance of varieties, time of maturity of rice in relation to the date of seeding. Optimum seeding dates for each rice area are determined separately using research data and practical observations. In the major rice-growing areas seeding dates should be selected so as to eliminate the risk of failure for rice to emerge by May 20. Proper seeding date for a variety of rice is important. The date of seeding a variety or varieties adopted in a locality is determined by soil temperatures apparent in the current season for the locality by the time of seeding. If the daily mean temperature at a 5 cm depth of soil is from 11 to 13°C, germination will be rapid because the top soil layer is heated more in the

daytime. The given range of temperatures may be considered suitable for seeding rice inasmuch as the lack of heat for late varieties from germination to seedling establishment is much less injurious than during ripening. Optimum dates for seeding rice vary from area to area. Thus, most seeding in the Kuban rice fields is done from April 20 to May 10; in the Don river ricelands, from May 5 to 15; and in the far-eastern rice areas, from May 15 to 25, also from May 3 to 5 for deep seeding.

From practical observations, late seeded rice is almost always uneconomical because, firstly, there is always a risk that even mid-season varieties might fail to mature when sown too late, and secondly, differentiation of the growing apex in the late-established rice occurs at high temperatures with the result of a severe reduction in the number of spikelets per panicle most of which might fail to mature.

The length of seeding time depends mostly on the occurrence of late frosts and length of the plant life cycle as influenced by the photoperiod and heat response of the variety. Essentially it is the difference between the length of the growing season for rice in an area and the shortest period of time required to mature a crop.

The latest practice based on water conservation has been to seed rice early and deep (at 4-5 cm) so as to obtain seedlings using natural moisture stored in the soil or brought by flush-irrigation waters. Early and deep-seeded rice is not submerged until the 2-3-leaf stage. Sometimes, on light and well-drained soils, intermittent flush applications may immediately follow seeding to until harvest under the condition that all flushwater that may be retained during applications in the check in low spots and hollows, if any, is removed. In the southern rice areas, early and deep seeding of rice is started on April 10 to 15, and in the far-eastern rice-growing areas, early May; not until the soil temperature at the 5 cm depth is about 8°C. Planting rice early and deep is suitable more for old riceland or new lands where the soil is nonsaline or, if otherwise, is properly leached, well graded and smoothed, and freed from weed growth by chemical or nonchemical methods. Early sown rices mature 10 to 12 days earlier and are more resistant to lodging than when seeded at dates normally adopted in the vicinity. Other benefits from early and deep seeding include increased average yields and improved grain quality. The practice helps reduce 10 to 15 percent the irrigation requirement and rate of seeding. Because rice ripens earlier and can be harvested at earlier dates during the season it provides better opportunities for fall plowing and land preparation for the next rice or a catch crop the following season.

This practice has been successfully used on 20-25 percent of the total rice acreage in the country. The success lies with proper water conserva-

tion practices, suitable seeding method that can provide a uniform depth and proper coverage of seeds.

If yield is compared, early rice seeding is more superior than inferior to optimum seeding in May and at a shallower depth. Thus, the 6-year average yield of rice seeded deep in April in one of the Kuban rice-growing farms was 6.18 t/ha, as compared with 5.53 t/ha from the May-established rice planted at depths about 1.5-2 cm in the same locality. From the above practice, returns to the grower were 0.65 t/ha more rice added to the average.

The longer the delay in seeding time, the lower the yield because the maturity period of mid-season varieties will be prolonged. On fields heavily fertilized with nitrogen, the plants will lodge more and produce more panicles with empty spikelets. In certain rice producing areas, such as the Northern Caucasus and the Far East, late-sown rices are ready for harvest only when the weather turns unfavorable and rainy causing heavy grain losses and deteriorating grain quality. The conditions for growth and development of rice are more favorable during the whole of the growing season if rice is seeded early in April. The relatively low air temperatures will suit the plants best from seeding to heading, and high temperatures will favor yield more from heading to maturity, than the same range of temperatures can do for rices seeded at usual or late dates in May.

Water Management

The application and management of water is a key operation in rice farming. Good yields are obtainable where the water management practices are well adjusted to the biology of rice varieties, soils, and weather conditions. The principal functions of water cover are to control weeds, to condition the soil, and to minimize the effect on rice of the fluctuation of the diurnal air temperatures which may be rather large in the Southern USSR.

Water is an ecological factor. There are two ecologically different types of rice: the *lowland* or *paddy rice* grown on land that is artificially flooded, and the *upland rice* that is grown without flooding in areas where annual rainfall is 1500-1800 mm. About 85 percent of the world rice acreage are in paddy or submerged rice. All rices in the Soviet Union are cultivated under submerged conditions that is under water depths between 15 and 25 cm. The varieties are very exacting for water application, and any trouble in water supplies results in poor grain yield.

The upland rice and "floating" or deep-water rices are not cultivated in this country.

Paddy rice is a semiaquatic plant, and its physiological needs for water during the growing period are different. Unless rice is water-seeded and the flood is maintained, no flood is needed during germination when the roots start to develop, and from the dough-grain stage to full maturity when roots almost cease to function.

In tillering, the fields are drained or water intake is discontinued to let the irrigation water be absorbed fully by the soil (but not let the soil dry out) to promote development of roots and shooting of the laterals. As soon as rice seedlings are established, a 10-15 cm deep flood is re-established and maintained until the crop is ready or nearly ripe to harvest.

The temperature of the water with which rice is irrigated has a profound effect on the plant. At seedling establishment, appropriate water temperatures are more important than air temperatures. Application of cold water is harmful for top and root development at all the physiological stages, and in flowering, in particular.

In rice production, the benefits from flooding the soil are recognized wherever the crop is grown. Beside satisfying the physiological requirements of rice for water, the aquatic environment has a profound influence on the microclimate within rice paddies. Floodwater regulates soil temperatures and increases humidity of the air immediately above the water surface. The layer of floodwater, creating waterlogged conditions, allows accumulation of essential nutrients in the form usable by the plants and as a carrier helps maintain them in the root zone.

Systems of Water Management

Water management systems in the world practice of rice production vary considerably. But essentially, all water applications revolve around four broad systems of water management, which are as follows:

(1) continuous submergence or flooding of rice paddies from seeding to until harvest;

(2) shortened flood-irrigation where seeding is done on dry ground and followed by flushing the soil to bring up emergence, the first flood of a variable depth being applied later. The field is drained several days before the rice crop is ready for harvest;

(3) intermittent flood-irrigation; and

(4) periodic or flush-irrigation without submerging the rice field, undertaken at certain phases of plant development.

Water applications under the first two broad systems of water manage-

ment are widespread and used on more than 90 percent of the world rice acreage.

Short-term flooding of paddies is used for almost all rice grown in the Soviet Union. This method best suits the biology of rice and permits the effective use of herbicides to control barnyard grass (*Echinochloa* spp.). Under this system of water management, seeding is followed by an immediate application of flush water to initiate germination and to bring up the rice seedlings (except for the deep-seeded rice). Only when seedlings have emerged (the 2-3-leaf stage) are the fields permanently submerged in water. Under this system, applications of irrigation water vary depending on the level of soil salinity, field infestation, the methods of weed control in use, and other factors.

Managing Water for Nonchemical Weed Control

In all cases, the rice field is flooded within one or two days after seeding to initiate germination. Large streams of water should be used for the first flood, but applied carefully to avoid erosion and damage to the soil structure. Submersion should be discontinued as soon as the layer of water is 10-12 cm deep. The duration of the first flooding is determined by using the initiation of seed germination as a guide. If the water has been absorbed, receded or dried out before the appearance of the first foliage leaf, the paddy must be reflooded. If the irrigation water has not receded by the time seedlings have been established, the field must be drained. The seed usually germinates on the fifth day if the water and soil temperatures are about 16-18°C. The germination stage is very important because lack of oxygen delays germination and results in thin nonuniform stands.

Unlike the seed of other grain crops, the seed of rice is able to germinate under anaerobic conditions. In such cases, the budlet of seed grows making the seed swell and rooted plantules are obtainable only when there is a free supply of oxygen. For this reason it is necessary to drain the paddy or let the water recede to bring about good emergence, increase seedling vigor, and obtain well-rooted plants. The above physiological feature of the rice plant has been cited as a means for justifying the concept of short-term flood-irrigation, i.e. letting the seed swell under water to initiate germination and letting the seedlings sprout out until the "awls" appear after the field is drained.

To control barnyard grass, the flood is repeated to a depth of 12-15 cm after the rows of rice seedlings emerge and sprout out their first leaf but before the barnyard grass (the most persistent of rice weeds) has

developed two leaves. As the grass grows, the depth of water is increased and maintained at 5-7 cm above the grass. Daily inspections and visual checks on the development of both the rice plant and the weed grass are mandatory. For lack of oxygen the grass leaf turns brown and dies within 12-20 days, depending on the water temperature. The higher the water temperature, the less oxygen it contains, so barnyard grass will perish more rapidly in warm water rather than in cold. One should not forget that deep submersion of the rice field may also affect the rice. It is therefore very important when the barnyard grass is killed to drain the water immediately to a safe depth for the promotion of emergence. Proper water management from seeding to full emergence usually results in good, uniform stands, free from barnyard grass.

At tillering (the four-leaf stage), the depth of water should be lowered to 5-7 cm and the flow of water to the field discontinued. Large depths at this period will produce 18 percent less tillers, affect the development of adventitious roots, and reduce yield. A shallow flood is thus maintained at tiller initiation. This is the best time to apply supplemental nitrogen. At the 6-7-leaf stage, the floodwater is raised again to 12-15 cm to control new weeds, the water is maintained except in special cases at about the same level until the crop is nearly ripe and the land may be drained for the harvest.

The daily top growth is highest from tube-formation to tasseling and accounts for 50 percent of the biological yield of rice. Interruptions in flooding during this short period are very harmful because of the complex physiological processes and intense vegetative growth occurring in the plant. A constant depth of water on the field is necessary during flowering to avoid floret sterility that impairs yield.

Draining of fields at the proper time before harvest is necessary to dry the soil enough to support harvesting equipment. It is equally important to decide on the time when water intake to the field should be discontinued, and on the rate of drainage. Rapid lowering of the water level is to be avoided because of the risk of lodging. Normally the field is drained at a rate of 1-1.5 cm per day to avoid bad lodging. If the irrigation water has not receded by the time the crop is nearly ready for harvesting, the field is drained. Rice growers soon familiarize themselves with the best time to drain the rice fields in order to permit harvesting and yet not permit the rice to suffer from lack of soil moisture. The usual practice is to discontinue the water supply and let the water recede and partially evaporate. This helps avoid lodging, and wasting irrigation water.

By harvesting time, the soil should be dry enough to support the heavy rice harvesting machines. Submersion of heavy, poorly drained soils

should be discontinued a few days before the final drainage of the field. The time to drain depends on soil type, drainage facilities, subsoil properties and weather conditions.

Managing Water for Chemical Weed Control

3′, 4′-Dichloropropionanilide: propanil and surcopur. Managing water for growing rice using this group of contact herbicides needs the special attention of the grower. Seeding rice on lands subject to treatments with the herbicides of this group is followed by flooding to a depth of 5-6 cm. For poorly leveled checks, the depth of water should be 7-8 cm. The field is drained as soon as most of the seeds germinate (after 5 days or so). Next, the field is flushed with water to keep the soil wet while the seedlings develop through the 1-3-leaf stage. While this is occurring, the level of water should be allowed to rise until it barely covers the surface of the field. Soon after, the field should again be drained. By the time the barnyard grass develops 2-3 leaves, the rice field is drained and the raised areas of land are allowed to dry for herbicide treatment (Fig. 33). No later than 2 days after the herbicide is applied the flood is renewed for 6-8 days. The time to apply a flood after herbicide treatment depends mostly on air temperature. At a temperature of about 30°C, the field checks must be submerged for 6 to 8 hours after treatment. This prevents the emergence of new barnyard grass, and kills the grasses that have already been treated. Delays in flooding or an inadequate water level in the field may bring about the germination of weed seeds lying on the surface of the soil (Fig. 34). During the rest of the growing period, water management in such fields is essentially the same as was described earlier.

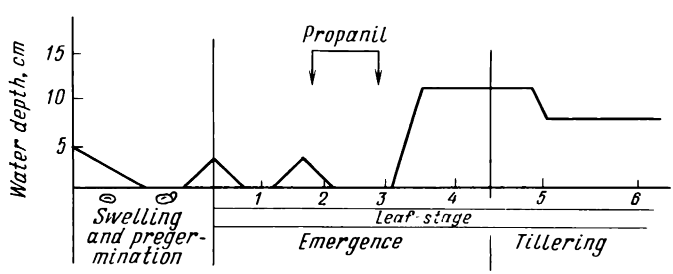


Fig. 33. Adjusting floodwater to 3,4-D herbicide treatments

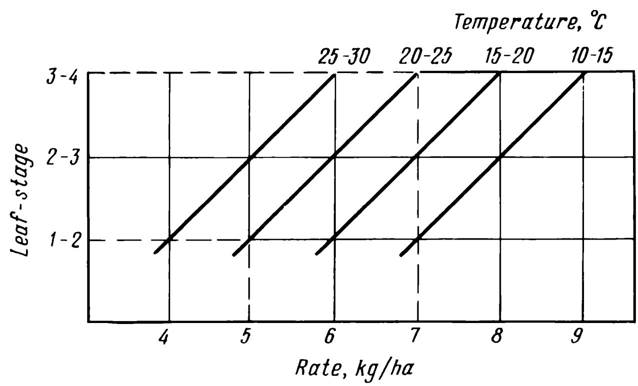


Fig. 34. Rate of herbicide 3,4-D related to weed age and air temperature

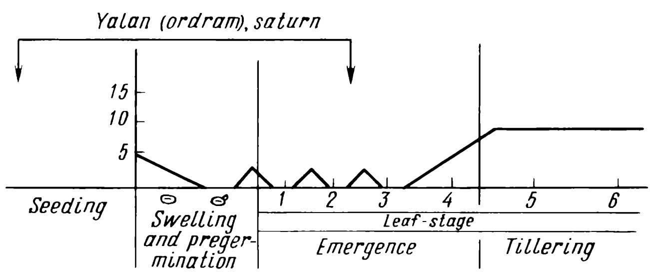


Fig. 35. Adjusting floodwater to soil-herbicide treatment

Soil herbicides. Soil herbicides, such as yalan (ordram), and saturn achieve best results when used on low-lying, waterlogged checks where the contact herbicides prove virtually ineffective. The herbicide treatment and seeding operations are followed by flushing of the soil. Drying out of the soil or deep flooding followed by rapid draining of the field are undesirable and should be avoided to prevent a loss of herbicides or a reduction in their efficiency. As soon as seedlings emerge and develop 2-3 leaves a flood up to 5 cm is applied and maintained until tiller initiation. During the rest of the growing period water management is about the same as previously described (Fig. 35).

Fig. 36. Aerial herbicide treatment of rice fields

Managing Water for Saline Soils

Unless adequate countermeasures are taken, rice yields on saline soil may decline sharply. Fields with saline soil are normally flooded to flush out harmful salts. The operation is done following fall-plowing. Soil tests are performed regularly to check the levels of salts in the field. Good drainage and chemical analysis are necessary for successful demineralization of rice soils.

Seeding is followed by establishing a 10 cm deep flood to achieve proper leaching of salts from the plow-line layer. Because of an excessive amount of salts in the soil, the water may rapidly become so saline as to be toxic to the rice seedlings. If so, it must be removed and fresh water applied.

Rice is most salt-tolerant during germination and most sensitive to salts during the 1- to 2-leaf stages. For this reason, if the water in the rice check contains more than 2 g salts per liter, the field is drained and fresh water applied. The land is drained for seedling establishment and for aerial treatment of the fields with 3′, 4′-D herbicides (Fig. 36). It should be kept wet, however, to avoid repeated salinization which is fatal to rice seedlings. Alternate flushing and draining is helpful in demineralizing the plow-line layer. The general rule for saline soil is not to allow the soil to dry out. This prevents capillary rise and repeated salinization. The field is covered with a 10-12 cm layer of floodwater following herbicide treatment and the development of 2-3 leaves on the young rice. Later, the water can

be lowered to about 5 cm to promote tillering. Highly saline water in the check during this period may delay seedling growth and cause yellowing of the leaf. To avoid this, the field is drained and fresh water supplied as soon as possible. During the rest of the growing period, the total salt content in the floodwater should not exceed 5 g/l, and the chlorine content 0.15 g/l. The water should systematically be checked for the content of salts toxic to the plants. Where salinity is extremely high, the water should be changed by alternately, as opposed to simultaneously, draining and flooding the field. Attempts to wash the salts away by simultaneous flooding and draining will not work because a forceful flow of water cannot reduce salinity uniformly throughout the check as is desired. In such cases, the water is renewed only around the inlet and within the water-stream zone, and remains stagnant down the field, and in the check corners where the water temperature and the salt content increase. In addition, constantly flowing water is often uncontrollable, adversely affects the downstream interests and overtaxes pumping and drainage facilities. Considerable amounts of salts accumulated in the irrigation water render it highly alkaline, and brown in color. Such water should be immediately drained and the field should be flooded once more. From tiller formation and for the rest of the growing season, a continuous 15 cm deep flood is maintained until the field is ready for harvesting, provided the topsoil in the checks is sufficiently salt-free.

Where rice is grown in saline soils, waste waters in the drainage and importation facilities should be maintained at a minimum level, or they at least should not exceed the rated water-line levels. The degree of salinity is checked by regular chemical tests, or by using the color of the water as a guide to renewing the supply. An experienced irrigator can determine if flushing or leaching of the soil has been sufficient by using the morphological characteristics of the soil as a guide to discontinuing the water supply.

Managing Water for Insect and Pest Control

The adopted system of water management should be changed whenever the rice fields are infested with those common pests of rice — rice midge and rice leaf miner.

Upon the appearance of either of these two pests (as determined by the presence of midge faggots in the water, or leaf miner faggots on the leaves

of the plants), one should lower the water level in order to topdress the rice with fertilizer, and allow the plants to increase vigor. The water is drawn down to zero level if damage to the plants is severe and the midge or miner faggot populations are large. Drainage of the rice checks should not cause the rice leaves to lie down and stick to the soil surface. If such is the case, or the soil begins to dry out, the field should be flushed or covered with a shallow layer of water. The field is not permanently submerged until 7 to 9 days after the midge faggots have died and the seedlings become established. Submersion of the fields is started normally with shallow waters. The depth is then gradually increased to the desired level. The water is also lowered down or drained to control tadpole shrimp (which is also a pest, although it is not an insect) should it occur in the rice fields in large numbers.

Managing Water for Early and Deep-Seeded Rice

Seeding rice as deep as 4 to 5 cm early in the spring requires some alterations in the adopted water management practice. The changes apply mostly to the initial period of rice development. Seedlings are grown without flooding of the field, but by using the moisture stored naturally, and conserved in the soil intentionally. Flush irrigations are applied only where the soil dries out, the seeding time is delayed, or the weather is dry and windy, and where soil moisture at 8 to 10 cm depths is insufficient for seed germination. In saline soils, one or two flushings should be done at the "awl" stage. During the rest of the growing period, a constant depth of floodwater is maintained until the crop is nearly ready for harvesting except in certain cases, such as excessive salt content up to 2.5-3 g/l, when the irrigation water should be partly or totally changed.

A flood (12-15 cm) is applied soon after the seedlings are established, grass herbicides used, and nitrogen fertilizer topdressed. The field is flooded gradually at first to prime the soil and is later built up to a depth of 6-8 cm so that the leaf blades of most of the rice plants are above the water surface. The depth of floodwater is raised from 10 to 15 cm with the growth of the plants. A deep flood (12-15 cm) applied in the beginning of plant life may cause some plants to die for the lack of oxygen under submerged conditions and thus cause thinning.

It has been common practice to maintain the 12-15 cm depth of water until the tiller initiation. As the fourth leaf appears, water intake is

discontinued and the water level is lowered to 5-6 cm, and maintained there usually for 8-10 days, and sometimes, for 15 days. The length of submersion for early deep-seeded rice is determined by stand density. The smaller the density, the more time is required for the plant to shoot out its laterals, and vice versa. A depth of 5-6 cm provides favorable conditions for the growth of buds, adventitious roots and laterals. It is appropriate at this time to topdress the rice with nitrogen to provide supplementary nutrition for, and increase growth of the young shoots. At mid-tillering, the rice field is treated with herbicides of the 2,4-D group to control clubrush. When all the tillers have formed the depth of floodwater is again increased to 12-15 cm, and is kept at that level until the kernels in the centre of the panicle reach the hard-dough stage. Such a system of water management for early and deep-seeded rice helps reduce the need for irrigation per hectare by 3 500 to 5 000 cu m, or by 15 to 20 percent.

Crop Tending

Tending crop is important for attaining a high level of rice production. Rice requires particular care during the first 3 to 4 weeks after seeding, i.e. when controlling weed growth may pose certain economic and technical problems. The primary objective, however, is to keep the field free from infestation by preventing weed and algae growth, diseases and insects outbreaks in the rice fields. Much of the grower's attention should be focused on proper water management and cleanness of the field checks. Trash that may come afloat during check flooding should be immediately gathered up, dried and burnt. At seedling establishment, areas with visible lapses and gaps in rice stands should be carefully re-seeded with seeds that have been soaked or, in bad cases, seedlings should be transplanted from crowded field areas.

Crop tending as part of rice cultivation is based on general principles of plant protection and on a specific system of disease and pest management which is adopted in each rice-growing area. A good knowledge of the weeds that compete with rice and of the diseases and insect pests of rice is essential for successful rice cultivation.

Weeds compete with rice for light, nutrients, space, and water; they also adversely affect the microclimate around the plant, and harbour diseases and pests. They reduce yields, lower the market value of the crop by reducing quality, and increase the cost of production, harvesting, drying and cleaning.

Slightly more than 250 species of plants have been registered as weeds that infest rice fields in the Soviet Union. Of these, about 20 species are persistent weeds that infest old ricelands, and some 10-12 species are weeds frequently found in crops that are grown in rotation with rice.

Weeds that infest rice fields differ from those that infest dryland and even irrigated crops. They are from the species that thrives best in extremely wet or flooded soil.

Plants that infest rice fields can ecologically be grouped as hydrophylous, marshy, aquatic and floating weeds, and algae.

Hydrophylous weed plants include barnyard grass (*Echinochloa contracta* Stev., *E. phyllopogon* Stapf., and *E. crus-galli* L.).

The weeds in this group are common to all rice-growing areas and grow equally well in waterlogged soils and fields flooded with shallow water. Prolonged and deep flooding is fatal for the young weed grass.

Barnyard grass is an annual plant and is the most persistent weed in seed rice and food rice plantings. Early in season it is often hard to differentiate between the young rice seedlings and those of the weed grass (Table 9) because of various morphological and biological characters that are quite similar in both species (Fig. 37). However, the rice leaf is more rigid, robust and rough than that of the barnyard grass which has a wider vein in the centre, and is a paler green. The stalk in rice is somewhat flat at the base, and it is round in barnyard grass.

One barnyard grass plant may produce from 600 to 800 seeds in average rice stands and from 3 000 to 6 000 seeds, in thin stands. The heat requirement of barnyard grass is about the same as that of rice. *Echinochloa* spp. germinates at temperatures not lower than 12°C in very wet or flooded soils. The optimum temperature for germination is from 20 to 25°C. Shed in the soil, the weed seed remains viable for 3 years; it may germinate and give seedlings in dryland from a depth of 6 cm when the soil is compact, and from 12 cm, when the soil is loose. It germinates

Table 9. Young Rice vs Young Barnyard Grass

Part of plant	*O. sativa communis*	*Echinochloa* spp.		
		E. phyllopogon	*E. contracta*	*E. crus-galli*
Stalk	Contracted	Contracted	Contracted	Spreading
Leaf	Light-green, long and narrow, first afloat then erect	Paler green, long and narrow, first afloat then erect	Darker, first afloat, then erect	Dark-green, broader and shorter, erect
Base of leaf blade	Ligule on lower leaf surface and auricules on both leaf surfaces	Rigid hairs on upper surface leaf sheath	Hairless, no ligule	Hairless, no ligule
Leaf sheath	Green	Green	Red	Red

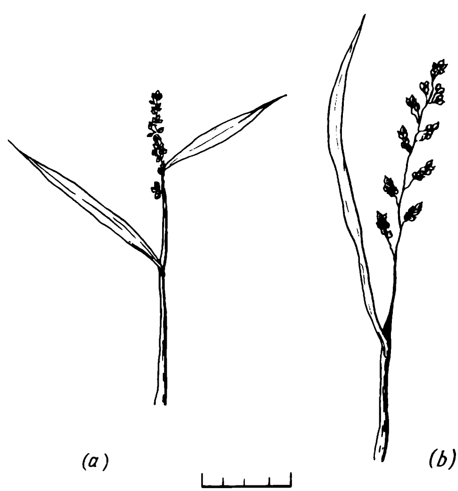


Fig. 37. Barnyard grass, *Echinochloa crus-galli*, inflorescence
(*a*) compact, (*b*) expanded

and sprouts seedlings from topsoil covered with a shallow layer of water about 1-3 cm.

Echinochloa contracta Stev. tillers well in rich soils and in thin stands. It can be long-awned, medium-awned, and awnless. All three forms of the species are subject to shattering, thus infesting rice fields badly. The weight of 1 000 grains varies from 6-7 g to 11 g. The matured seed has no dormancy period and, since it sheds in wet ground, it germinates rapidly from late September to early October when the soil is sufficiently moist, the weather warm, and temperatures about 16-18°C. In the spring, the seed of the weed sprouts from a soil depth of 1-12 cm as soon as the soil temperature reaches 12-14°C. By late May, its germination percentage is about 93-98. The best soil conditions for sprouting are a soil moisture content of about 90-100 percent of the least field capacity, and a temperature of 20 to 25°C. In the spring, 100 percent of the weed seeds germinate and sprout from a 1-3 cm soil depth; 80 percent from a 5 cm depth; and 56 percent from a 10-12 cm soil depth in rice fields where a flood about 15 cm deep is maintained. After a year in rice, about 20 percent of the seeds within a soil layer from 0 to 20 cm may still be viable.

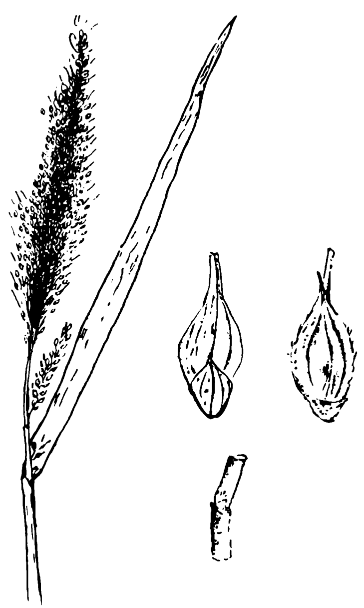


Fig. 38. Barnyard grass, *Echinochloa phyllopogon*, inflorescence, spikelets, node

The young grass can stand shallow water, but a flood of about 25 cm would be fatal.

Echinochloa phyllopogon Stapf. can be either awned or awnless. The awnless forms shatter more and infest rice soils directly. The awned forms are more resistant to shattering and infest rice fields through uncleaned seed rice. The weed has a well-developed root system and produces many tillers. 1 000 grains weigh 4-7 g. The seed is not dormant and germinates rapidly producing vigorous seedlings at excessive soil moisture and at soil temperatures of 14-15°C. The young weed grass can stand deep water, but floods up to 25-30 cm in hot weather will kill the weed within 5 to 7 days. Morphologically *E. phyllopogon* is closer to rice than other forms of the species and has about the same maturity period (Fig. 38). The seed of the weed buried deep in the soil remains viable up to 5 years, and is able to sprout in compact soil up to 10 cm deep. The seed, however, fails to produce seedlings from a soil layer of 2 cm under submergence, but the established seedlings can stand deep water for the rest of the growing period.

Echinochloa crus-galli L. can be long-awned, medium-awned, or awnless. The long-awned forms usually infest fields where rice is cultivated under continuous submergence. The weed can sprout from a soil depth of 3-5 cm in a field with a 10 cm deep water cover, but it fails to produce seedlings through a layer of water as high as 15-20 cm.

Because they are ecologically closer to dryland weeds, the medium-awned and awnless forms normally infest rice fields under rotational irrigation. These forms of barnyard grass mature even earlier than do the early rices, and shatter more than other weed grasses. The small-sized seed has a period of dormancy (Fig. 39). The 1 000-grain weight varies between 1.5 and 2.0 g. Once shed, the seed volunteers in early April from a soil depth of 1 cm, but not until mid-April from a depth of 3-5 cm. In the spring, up to the time for seeding rice, about 80 percent of barnyard grass seeds present in a soil depth of 1-5 cm will emerge, and about 50 percent will sprout in a soil layer between 0 and 20 cm, provided that air temperatures are 12 to 23°C and soil moisture accounts for 70 to 85 percent of the least field capacity. When irrigation water is provided from April 16 to May 20, about 28 percent more seeds that survived the winter within the 0-20 cm soil layer will emerge. However, about 17 percent of such seeds will still remain within the rice field. Under rotational irrigation, water applications for crops other than rice (usually grasses) can, during one summer in a dryland crop, yield up to 95 percent of barnyard grass plants from the 1-25 cm soil layer. *E. crus-galli* is a viable plant that grows back every time the main crop of grass is cut.

Fig. 39. Barnyard grass, *Echinochloa crus-galli*, inflorescence and spikelets

Rice cutgrass (*Leersia oryzoides* L.), a perennial grass, has recently become a problem in Uzbekistan, Kazakhstan, and in the Northern Caucasus. The weed grass infests primarily rice fields under rotational irrigation, and also irrigation ditches. It propagates by seed and other propagules, called rhizomes. During its growing period one rice cutgrass plant produces rhizomes up to 1 m long with 12-15 internodes. The winter buds start to grow in the spring when temperatures are from 8 to 12°C.

Fig. 40. Common reed, *Phragmites communis*, inflorescence and rootstock

The culm of the plant varies in height from 50 to 150 cm, and its leaf is sharply indented on the edges. The inflorescence is an expanded panicle up to 18 cm long, that bears many spikelets (from 500 to 700).

Marshy weed plants are largely perennials that infest fields which are continuously in rice, as well as low-lying field checks which are waterlogged most of the time. The weeds in this group thrive exclusively on waterlogged and submerged lands, and can withstand deep water and prolonged submergence. The weeds propagate by seed, and by vegetation. Their propagules are rhizomes, tubers, or root-tubers. These start to grow in the spring at soil temperatures about 10-11°C. Because its seedlings usually emerge earlier than those of rice, they compete vigorously with each other for the growth essentials.

Common reed (*Phragmites communis* Trin.) thrives in waterlogged areas and ricelands where table water is high. It propagates vegetatively through its well-developed rootstock that penetrates soil to 1.5 m, as well as through above-ground propagules that creep over the soil surface (Fig. 40). The common reed has no special soil requirements and grows well in both saline and good soils.

Bulrush (*Boldoschoenus compactus* Hoffm.) and clubrush (*B. maritimus* Palla) are sedge weeds. The stalk is 85 cm tall, and triangular at the base. The leaf is long (70 cm), narrow, and rough. The mature seed is small and dormant, and is shed long before the early rices are harvested (Fig. 41). Most of the seeds (up to 50-80 percent) overwinter

Fig. 41. Bulrush, *Boldoschoenus compactus*

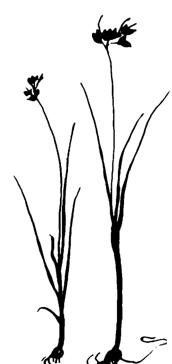


Fig. 42. Clubrush, *Boldoschoenus maritimus*

on check surfaces, then germinate and produce shoots in the spring when temperatures stabilize about 20°C and soil moisture approaches field capacity. Seedlings may even grow through a thin sheet of water about 1-2 cm (Fig. 42). In the soil, the seed remains viable for about 5-8 years. Both forms propagate by seed and by tuber. During one season, each tuber lying at a depth of 11-15 cm produces from 10 to 47 new tubers, and in a

year old grassland, up to 11 tubers. Tuberization occurs primarily within the 2-10 cm layer of soil. In old riceland, the number of tubers within the depth of the plow-line may sometimes be as high as 1 000-2 000 tubers per sq m. Tubers that are buried at a depth of 20-23 cm for more than 3 years lose about 70-75 percent of their viability. Drying and freezing of the soil in old riceland markedly reduces the viability of propagules within the top soil. Drying of the soil (i.e. soil moisture under 14 percent) is fatal to tubers.

Spikerush (*Junceilus serotinus* Rottd.) is another persistent weed of the sedge family. The triangular culm is about 1 m tall. It propagates by seed and by rootstock. The seed's dormancy and germination rates are about the same as in bulrush seed. Propagation is however usually vegetative, through the rootstock. One fruit-bearing organ produces up to 47 new cord-like rhizomes in one season. The rhizomes are spaced at 3 to 20 cm apart and sit at the end of the old rootstock. Freezing and drying of soil is lethal only to the surface-confined rhizomes.

Common cattail, also mace reed (*Typha latifolia* L.) and narrow-leaf cattail (*T. angustifolia* L.) are perennial weeds with a thick, creeping rootstocks buried at a depth of 5-10 cm. These weeds have a 2 cm and a 0.5-1.0 cm broad leaf, respectively. Both weeds propagate by seed and by rootstock. The small-sized seeds have a pappus, and are grouped into cylindrical inflorescences, each containing up to 450 000 seeds. The seed germination rate is about 100 percent in the year when the plant flowers. The seed produces shoots at temperatures no lower than 20°C in overwet soils, or fields with a thin water layer (Fig. 43). Draining of fields and drying of the soil kills the young plants. The weed infests mostly irrigation and drainage ditches, and newly developed rice lands; it also thrives where cultural practices are poor.

Common water plantain (*Alisma plantago aquatica* var. *maritima* L.) is a perennial weed that infests rice fields in the Ukraine, Northern Caucasus, Kazakhstan and Uzbekistan. Oriental water plantain (*A. plantago asiatica*) is a weed that causes problems in the Far East rice lands. It is a prolific plant that propagates by seed and by tubers. Its maturity period is shorter than that of rice. The matured seed shatters and thus infests rice soils. One plant is able to produce anywhere from 15 000-20 000 and more achenes with a high seedling vigor. The seed germinates rapidly both in soils with a moisture that is close to field capacity, and in submerged soils with a floodwater temperature of 15-18°C. From the 1 cm layer of submerged soil, water plantain emerges shortly after rice and competes with the rice seedlings for strength and becomes robust until the rice row-stands close. The competition is particularly vigorous where the stands of

Fig. 43. Common cattail, *Typha latifolia*, in rice planting

crop are thin. Weed shoots develop from the buds that sit on the propagative tubers, and soon appear to form leaves (in June and early July) that float on the floodwater surface, shading and suppressing the young rice.

When buried in wet soil, water plantain propagules with auxiliary buds can remain viable indefinitely, and are able to withstand heavy frosts. Even a mild frost, however, can kill tubers when they are brought to the surface during soil cultivation. Smoothing underwater check surfaces following land preparation operations during the summer is considered an effective means of controlling water plantain.

Pickerel weed (*Monochoria korsakovi* Regel et Meack.) is an annual broadleaf weed that can survive in deep water. Pickerel weed usually infests rice fields and irrigation and drainage ditches. It is common in the far-eastern rice producing areas and is a major weed where rice is shallowly seeded. Outbreaks of *Monochoria* have been recently reported in the Northern Caucasus — particularly in the Kuban delta ricelands.

Fig. 44. Pickerel weed, *Monochoria korsakovi*, seedling

The mature plant is 50-60 cm tall, and has a succulent stem with thick, broad leaves. It propagates by seed which is enclosed in a ball with a large pericarp. One *Monochoria* plant produces up to 20 000 seeds. The mature seed germinates well in a soil with a moisture close to field capacity, or in flooded soil. The young weed plant (Fig. 44) usually emerges in rice fields from mid-June to early July. The weed is susceptible to shade. A good rice stand will suppress *Monochoria* in that a large number of the plants will die for lack of daylight. Most of the remaining plants (up to 95 percent) fail to produce inflorescences and, therefore, do not flower. The weed, however, thrives in thin stands and then competes vigorously with rice, thus reducing grain yields. An efficient means of controlling *Monochoria* is to sow rice early and deep, thus permitting seedlings to be obtained using naturally stored moisture. An additional means of combatting the weed is to level the fallow fields when they are under water.

Arrowhead or duck potato (*Sagittaria trifolia* L.) is a perennial plant with arrow-shaped leaves. It propagates by seed and tuber forming stolons at depths ranging from 6-9 to 15 cm. These are underground shoots bearing about 8 tubers at each end. The tuber has a crown bud from which a seedling can develop earlier than from the seed itself (Fig. 45). At soil depths of 20-25 cm, the tubers remain viable for about a

Fig. 45. Arrowhead, *Sagittaria trifolia*, plant with stolons

year or so. Drying of the soil kills tubers, while a layer of water stimulates the tuber-developing seedling, which can survive in deep water and can break surface through depths of up to 50 cm. The small-sized seed remains viable for about 5 years.

Aquatic weeds include both the annuals and perennials which can grow and bear fruit while immersed, or floating on the water surface. Some of these weeds propagate by seed (chara and naiad), others both vegetatively and by seed (pondweeds). Drying of the soil is harmful to all the weeds under this group.

Chara (*Chara* spp.) and naiad (*Najas minor* All.) are annual weed plants, 15-20 cm tall, that propagate by seed. They infest mostly the irrigation canals and rice field areas around turnouts. Drying of the fields for 2-3 days kills the weeds.

Clasping-leaf pondweed (*Potamogeton perfoliatus*), floating pondweed (*P. natans*), and common pondweed (*P. pusillus*) are perennials that propagate both by seed, and vegetatively. The shallow-rooted rhizomes are able to easily break from the soil and are dispersed by flowing water. The weeds are unable to tolerate dry conditions and therefore infest primarily irrigation and drainage facilities, as well as fields where rice is grown continuously. The economic losses attributable to these weeds are large. They infest waterways, thus greatly reducing the water-carrying capacity of the

delivery canals by raising the water level in the drainage ditches. This, in turn, causes the water table in the non-irrigated downstream lands to rise, thus injuring, or sometimes killing the dryland crops grown there. Proper choice of rotational crops can effectively control these weeds.

Floating weeds thrive in rice fields and drainage and irrigation ditches. This group includes ninebark (*Physocarpus* Max.), duckweed or duck's meat (*Lemma* L.), horned pondweed (*Zannichellia palustris* L.), and many others. These weeds are mostly annual and propagate by seed.

Algae (*Algacea*) are lower plants several unicellular and multicellular forms of which commonly infest rice fields. When temperatures are high, algae of various sizes and shapes rapidly develop colonies in the water (usually in mid-May and June). One such algae is diatom (*Diatomeae*) which is the first to appear. Others are green algae (*Chlorophyceae*), blue-green algae (*Cyanophyceae*) and brown algae (*Phaeophyceae*). All these algae frequently form scum that deposits a dirty film on the emerging rice seedlings which retards and frequently prevents further growth of the young rice plants. Algae scum is most harmful during emergence of the rice plants.

Weed Control Practices

Effective systems of weed control combine preventive, mechanical, cultural and chemical methods. Nonchemical methods include several or all of the following practices: using weed-free seed rice, crop rotations, seedbed preparation and land levelling, selecting the proper methods of seeding and water and fertilizer management. Chemical methods are based on the use of herbicides that effectively control weeds in rice if applied properly and timely.

Nonchemical Weed Control

Weed control practices differ depending on the species and amount of weeds, the structure of cropped acreage in the rotation, the availability of irrigation water, drainage conditions in the rice fields, and rice varieties.

The nonchemical practices can be preventive, mechanical and cultural. Proper combination of some or all of such practices will provide an effective weed control system.

Practices that prevent weed infestations or their spread in clean fields include the use of high-quality seed rice that is free of weed seed, irriga-

tion with water that is free of weed seeds and other weed propagules, and cultivation with clean equipment.

Plowing, disking, harrowing, rotary tilling or combinations of these mechanical methods are used to prepare rice fields, seedbed and eliminate young weeds. In new ricelands, presowing tillage of fall-plowed fields or spring plowing is done several days before seeding to level the check surfaces and make a fine tilth in the top layer (8-10 cm). One of the main goals of all methods of seedbed preparation is to eliminate all weed growth up to the time of seeding. Deep plowing in the fall (up to 20-25 cm) with inversion of the soil layer to turn down the topsoil infested with weed seeds, and subsequent tilling in the spring without inversion (subsoiling or chiseling) so as not to bring the seeds to the surface is a good practice to control barnyard grass and other gramineous weeds. The method chosen depends on type of soil, soil condition (mellowness), other crops in rotation, the method of seeding, climate and the kinds of weed present. Primary cultivation usually provides good conditions for weed seed germination and emergence, and subsequent cultivation eliminates young weeds and conserves soil moisture. Old weeds that may survive on incomplete seedbeds are not so easy to control, therefore thorough preparation is important.

In the major rice-growing areas, the old riceland is harrowed late in March or in April to bring up barnyard grass. The rice fields are then disked and harrowed again to eliminate young weeds. If the spring is dry, the old rice fields are flushed one or two times to provoke weed emergence 6 to 10 days before weed control cultivations. The number of presowing soil cultivations needed to control barnyard grass depends on how compact the topsoil is.

The seeding method influences weed problems. The depth of tillage, regardless of implements used, should not exceed 5-6 cm in the field where rice is to be drilled, and is unlimited in these areas where the rice is broadcast onto the dry ground or in water. Time intervals between weed control cultivations and between seeding the rice and flooding the soil should be minimized. If this condition is satisfied, the layer of water will prevent the emergence of the barnyard grass whose seeds are only 2 cm deep in the soil. Firming the soil with a roller-packer is a good way to bring up weed grasses due to the capillary rise of water to the topsoil, usually infested with weed seeds. On the average, the rate of weed emergence per square meter on ground that has been firmed is twice that on unpacked ground. The young weeds that emerge after soil firming are easily eliminated by proper cultivations. However, the barnyard grass that emerges along with the drilled or dry-seeded rice is difficult to control by

cultural or mechanical methods. Water seeding reduces the growth of barnyard grass and other weed grasses during rice emergence. Herbicides are essential for controlling annual grasses that infest dry-seeded rice, and other weeds that infest water-seeded rice such as the aquatic weeds and sedge.

Land leveling and proper construction of levees permit a uniform depth of water to be maintained in the check and reduce infestations. Properly leveled land also reduces the number of sites available for weed growth. Annual weed grasses are usually more abundant on ridges and along field margins where water does not cover the land uniformly. Some immersed aquatic weeds grow only in shallow water, and are thus more abundant in low areas where surface drainage is inadequate. Therefore, effective weed control requires that leveling operations be performed thoroughly throughout the check effective area.

Water management before and after seeding rice often determines the kinds of weeds in the field and affects the severity of infestations. Flooding the field to 20-30 cm depth of water kills the barnyard grass within 5-7 days, if the water surface is 6-7 cm high above the top of the weed grass and the water temperature is above 20°C. Flooding the field for water seeding decreases problems with weed grasses but increases problems with aquatic growth. Controlling certain forms of barnyard grass by flooding requires a good knowledge of weed biology. Young barnyard grass, for example, is susceptible to flooding because it fails to emerge through a layer of water that is 15-20 cm. Larger depths up to 25-30 cm are required to control *Echinochloa phyllopogon*. However, such flooding has a narrow margin of safety for the rice seedlings, retards tillering, and may also increase aquatic weed growth.

Mechanical weed control is helpful for rices that are sown early and deep (up to 4-6 cm) and whose emergence is brought about not with flush or flood irrigation, but by using natural moisture. Methods include working over the rice field in the spring two times with a rotary harrow to which a spike-tooth harrow is attached. This cultivates the field before rice-seeding and eliminates weed grasses. The field is worked over again in the same manner after emergence when the rice has formed 2-3 leaves. Rotary hoeing after crop emergence controls small weeds in dry-seeded rice. It is a practical method of cultivation after seeding and is effective when the soil in neither too dry, nor too wet. A 10-15 cm deep flood of water is then established on the field checks. In the Far East, barnyard grass is also controlled by harrowing the rice fields four times over — twice before and twice after emergence.

The occurrence of a particular weed species in rice is often associated with the adopted crop rotation. Rotating rice with perennial grasses and

cultivated fallows helps efficiently clean the riceland from weeds. In the USSR RRI experiments, rotating rice with cultivated fallow fields controlled 95 percent of the soil-borne barnyard grass seeds and 75 percent of bulrush propagules.

Good drainage and subsequent soil drying has been effective in controlling marshy weeds, such as bulrush and other perennial weeds that form large root stock or rhizome systems, tubers, or winter buds in the soil. Adequate surface and ground water drainage from the time rice is harvested (September) to its next seeding (April, May) improves the control of sedge weeds and conditions the soil after fall-plowing. Such drainage also increases the harmful effect on rhizomes of the changing temperatures that occur during the transition from winter to spring.

Common reed is a problem weed in new ricelands, in lowland areas, or wherever the water table is high. Biologically speaking, the term common reed refers to any marshy weeds that can stand deep water. In rice fields, common reed efficiently competes with rice, depletes rice soil and suppresses rice seedlings. Weeding operations require much labor. The control practices are mostly based on first deep plowing to break up, dry, and freeze weed propagules, and then flooding the rice field the following season. The Uzbek SSR Rice Station has tested the resistance of the reed rhizome system to freezing and drying, and to mechanical damage before a flood is applied. The best results with freezing were obtained when the sum of negative temperatures during 45-60 days accounted for 330-360°C. The freezing effect on the rhizome increases if fall-plowing is deep and done with a skimless plow. The effect of freezing should be assisted by drying the rhizomes in the summer. Drying out of roots and other propagation parts of sedge weeds is an effective means of control particularly in the riceland or lands that are to be in rice the following season. This practice is very effective provided the land areas are well drained and safe from inundation by the irrigation or ground waters. Adequate surface and ground water drainage is essential.

Plowing the riceland in June and subsequent drying for 60 days more with a total of 1 500°C temperatures during this period gave good results in sedge weed control. Where the climatic conditions are favorable, controlling weeds by drying can be successfully carried out during the whole of the warm weather season, from June to October. The season may include 4 periods, 60 days each.

Disking rice fields with a disk harrow is another good method of controlling sedge weeds. Disking breaks up the rhizomes and the subsequent application of the first flood for 3-4 days kills most of the propagules of these perennials.

Draining the fields and drying the soil for 2-3 days is a well-known method for controlling aquatic weeds and algae. Draining the field immediately after areas of algae appear on the soil and then alternately flooding and draining the field again until the rice plant is tall enough to shade the soil and the water also controls algae growth.

Chemical Weed Control

In the cultivation of rice in the Soviet Union, herbicides have become important tools in the light of reducing weed losses and increasing the efficiency of other cultural practices. The choice of herbicides depends on the weather, the character of weed infestation, and the biology of the weed plant.

Most of the herbicides that are used in rice fields are highly selective. Some (propanil, surcopur, saturn and yalan) are effective only on weed grasses, while others (2,4-D, 2M-4X, basagran) are for use exclusively on sedge and broadleaf weeds.

Contact and systemic herbicides applied (and harrowed to cover) before seeding rice and flooding the field provide adequate pre-emergence control of young weeds and barnyard grass. Yalan and saturn are used for pre-sowing treatments. They are applied and harrowed into the soil to a depth of 3-5 cm 2-3 days before seeding rice, or immediately after seeding and flooding. Adequate coverage of herbicides in the soil is necessary because these herbicides volatilize and rapidly lose their efficiency. Saturn can also be used for post-emergence applications when rice reaches the 2-leaf stage.

The application of herbicides requires a fine tilth of soil within the 3-5 cm top layer loose enough to readily mix with the herbicide. Such a mix is used to retain the herbicides in the target area, and to keep them from being washed away by the irrigation water. Herbicide distribution should be uniform over the entire field. This is achieved through harrowing the field to cover the herbicide and avoid those lapses which later tend to become the most likely sites for weed infestation. Soon after the herbicide is applied, no more soil-moving operations should be allowed on the field (levelling or floating) to avoid disturbing the uniform distribution of the chemical.

Herbicides are diluted with water and the resultant emulsion is usually applied at a rate of about 250-500 and 100 l/ha by aircraft or tractor sprayers. Applications of yalan and ordram (molinate) at 4-7 kg/ha[1] or of saturn at 4-5 kg/ha kill barnyard grass in rice fields within 7 to 10 days.

[1] Hereinafter all application rates refer to active ingredients.

These soil herbicides remain residually effective for one or two months after application, provided the water management required by herbicide use is adequate. Herbicide treatment of good soils rich in organic matter is less effective, as herbicides lose efficiency 1.5-2 times faster in good soils than in problem soils.

Applications of yalan, ordram and saturn by aircraft sprayers are usually rare and resorted to only in rainy weather or after emergence when use of ground or other kinds of application equipment is impractical.

Where herbicides are applied both after, and before emergence, the rice seedlings are usually brought up without a flood but with flush-irrigation applications. At this time, one must avoid even short-term drying of soil, particularly saline soil, and unnecessary drainage since this leads to a loss of herbicides and a reduction in the effectiveness of the treatment. The first sustained flood is applied when the effect of the herbicides becomes apparent which in rice usually occurs at about the 2-3-leaf stage. Saturn is also applied after emergence to flushed soil, and a flood up to 7-10 cm deep should be applied no later than 2 days after.

Contact herbicides (propanil and others) are usually applied after emergence to control weed grasses. Flush irrigation applications are used to bring up rice in the field and the last flushing is done 2-3 days before herbicide treatment. The water in low spots should be removed and the soil in raised patches allowed to dry out slightly. In saline lands, where drying should be avoided herbicides should be applied onto wet soil at rates 1-2 kg/ha higher than usual.

The best rate of herbicide application can be found by using the data from Table 10, which takes into account the age of weed plants and the air temperatures during treatments.

Table 10. Rates of 3,4-D *vs* Plant Development Stage and Air Temperature

Barnyard grass (leaf-stage)	Application rates, kg/ha, at air temperature, °C			
	25-30	20-25	15-20	10-15
1-2	4	5	6	7
2-3	5	6	7	8
3-4	6	7	8	9

Recent investigations have indicated that not all rices are equally tolerant to the herbicides 3,4-D. Some varieties, such as Dubovsky 129 and Kuban 3 are very susceptible to propanil, while Alakul'sky and Donskoy 63 are more tolerant. Propanil does not injure Krasnodarsky 424 and its use does not reduce the yield of this variety.

Propanil and its analogues are usually applied by aircraft sprayers at a rate of 50-100 l/ha. Highly concentrated herbicides 3,4-D (propanil, surcopur with 50-55 percent active ingredient) are not diluted with water, and are applied by specialized small-volume sprayers. The application rates of concentrated emulsions of these herbicides range from 8 to 10 l/ha. Because the effect of pure formulations is more prompt, it is best to use them in cool and rainy weather (a practice which is forbidden in Uzbekistan and the Far East). Propanil, however, fails to control weeds which emerge after treatment. As a contact herbicide, propanil is effective on rapidly growing weeds that emerge by the time of treatment. Propanil does not control weeds residually, but flooding the rice field to a depth of 10-12 cm within 2 days after treatment (5-7 kg/ha) usually kills such weeds or prevents more weeds from germinating. At higher rates (8-9 kg/ha) the rice field should be flooded within 3-4 days after treatment.

The USSR RRI tests in the Northern Caucasus and the Crimea have proven mixtures of herbicides to be very effective in controlling weed grasses (barnyard grass). Beside fast toxic action on the young weed grass, herbicide mixtures control grasses residually and are effective on young bulrush. Mixtures of herbicides are applied post-emergence when weed grasses are in the 1-3-leaf stage. Mixtures are applied to drained fields on a wet or slightly dried soil. Propanil (3-4 kg) is normally mixed with ordram or saturn (2-3 kg) before use, and the mixture is applied by aircraft sprayers at a rate of 100 l/ha, either diluted or in its pure state.

Systemic herbicides, 2,4-D or 2M-4X, and basagran effectively control bulrush and broad leaf weeds (water plantain, arrowhead, Pickerel weed, etc.). These herbicides are highly selective and mobile within the plant thus affecting top growth and the root system, both of which are particularly important for controlling problem perennial weeds. The timing of herbicide treatments, which is determined by the age and physiology of not only the weed plant but also the rice plant, is very important. The reaction of rice to 2,4-D varies with the variety, rate and time of application. Early rices are usually more susceptible to this group of herbicides than the mid-season or late varieties.

The application of systemic herbicides from emergence to tiller formation is not desirable and may significantly injure rice and reduce both stand density and grain yield. The optimum or less injurious applications are from mid-tillering to the leaf-tube formation.

The herbicides 2,4-D or 2M-4X are usually applied to shallow-flooded rice fields (7-10 cm) when the weeds have reached the 8-10-leaf stage for bulrush, or the leaf-rosette stage for water plantain, arrowhead, etc. The optimum rates of herbicide application on marshy weeds are given in Table 11.

Table 11. Application Rates for the Control of Marshy Weeds

Herbicide	Rate (ac. sub.), kg/ha	Rate (diluted suspension), l/ha
2,4-D amine salt	1.2-2.0	50
2M-4X	1.0-1.5	50

At high temperatures (25-30°C) the rates of 2,4-D applications should be reduced. Maximum rates are used on rice fields when the weather is cool (15-20°C) and rainy.

Copper sulfate put in small cloth-sacks at turnouts is applied to the irrigation water to prevent the large-scale appearance of algal colonies. Copper sulfate applied at a rate of 3-5 kg/ha controls initial algal formations and algal development on the soil. It is most effective when applied at a rate of 250-400 l/ha to separate algal colonies by hand sprayers. Where algae become a problem in large areas, a 1%-copper sulfate solution at rates not less than 100 l/ha may be beneficially applied by airplane sprayers. It must be remembered, however, that if water with copper sulfate is transferred from the rice field into the irrigation system, fish and other aquatic life may be injured.

5

[illegible]
AND THEIR CONTROL

The importance of insect pests is generally recognized; the damage they do is widespread and very evident, but the loss of crop caused by diseases should not be overlooked or considered negligible. The crop is liable to many diseases any one of which may suddenly inflict widespread damage.

In recent years the effect of plant protection has significantly increased. Although average losses in most fields have been appreciably reduced due to adequate plant protection measures, losses in individual rice-growing areas and fields from specific diseases and pests are at times high and markedly reduce the total grain output in the country.

Practical plant protection includes not only destructive measures, but also the use of resistant rice varieties, methods that result in unfavorable conditions for the development of injurious organisms, and practices that conserve useful enthomofauna. Such protection also allows one to control economically important pests which rely on population thresholds by using, in the first place, natural limiting factors, and then other plant protection methods that are consistent with economical, ecological, and toxicological requirements.

Rice Diseases

Most of the world's major rice diseases are known to occur in the Soviet Union.

Blast, for one, is a major disease caused by the fungus *Pyricularia oryzae* Cav. It occurs in almost all rice-producing areas and is the most noxious disease of rice (Fig. 46). The fungus mostly attacks the leaves and to a lesser extent, the nodes and panicles. The disease results in both leaf blast and head blast. The latter condition is where the panicles frequently break over due to infection-weakened structural tissues in the panicle and is sometimes known as *rotten neck*.

Atmospheric moisture and temperature conditions are of primary importance in the infection and spread of the fungus that causes blast. Frequent rains, heavy nightly dews, high relative humidities and temperatures (18-20°C) favor wide-scale outbreaks of the disease. Rice plants under high levels of nitrogen fertilization are more susceptible to blast. The outbreaks of disease may be caused by use of susceptible varieties or uncleaned seeds mixed with the seeds of varieties consistently susceptible to blast. Blast is heavier on late-sown than on early-sown crops. The infection is persistent in seeds, on the stubble, in straw and reed growths.

Fig. 46. Blast, *Piricularia oryzae*. Culm drawn from sheath showing shrivelled areas with dark grey hyphae and conidia $\times 1$.

The average losses in yield of the fungus-affected plants account for 25 percent. The milling yield of head rice is decreased by about 23-25 percent. Treatment of the rice crop infected with *P. oryzae* includes spraying with 0.4% zineb solution (80 percent wettable powder) at a rate of 2.4 kg/ha, or with rhizid P (50% emulsible concentrate) at a rate of 0.5-1.0 kg/ha, in terms of the active ingredient. The rate of application is 200 l/ha. The treatment of the crop should be completed 20 days before harvesting.

Preventive measures include early fall plowing, seeding with clean certified seed from the varieties selected best for that area's growing season, the application and uniform distribution of nitrogen fertilizer, and seed-dressing or disinfecting with colored granosan M dusts at 0.04 kg (active substance) per ton of seed.

Other rice diseases, such as *brown spot* (*Helminthosporium oryzae* Breda de Haan), *sclerotical rot* (*Sclerotium oryzae* Wt.), *root rot* (*Achlya*

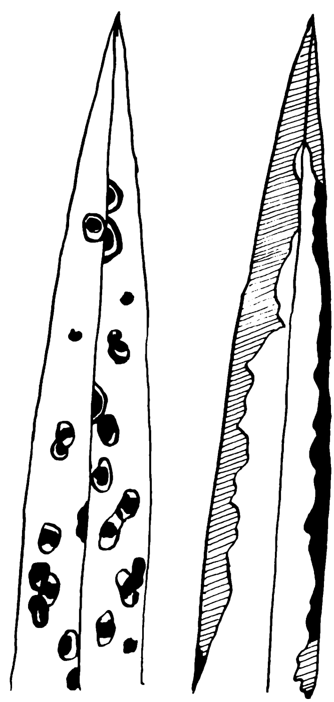


Fig. 47. Brown leaf spot, *Helminthosporium oryzae*, (left), and bacterium *Xantomonas oryzae* (right)

spp., *Pythium* spp.) and *bacterial disturbances* (Fig. 47) are rare, and of less economic significance.

Recommended control and prevention practices against fungi and bacteria attacks include the removal of rice straw, burning of plant residue, deep fall plowing with inversion of the soil layer, and rotational planting (with cultivated fallows and leguminous grasses). Seed-dressing with colored granosan M dusts (0.04 kg/ton, active substance) is mandatory.

General symptoms of rice diseases are abnormal plant growth and changing leaf color. A disturbance in plant development manifestes itself in retarded growth and excessive or reduced tillering. The stems and leaves may develop galls or cecidia, streak mozaic and necrotic areas. The leaf may change its coloration from green to yellow-green or yellow-orange. Diseases are transmitted basically by suctorial insects. To prevent the spread of such diseases rice fields are treated with phosphororganic substances in the early stages of plant development to kill cicads (*Cicadidae*), insect vectors of virus and micoplasma, inhabiting clumps of grasses, particularly barnyard grass.

White-tip disease of rice, caused by an ectoparasitic foliar nematode, *Aphelenchoides besseyi* Christie, is another widespread noxious disease of rice.

The most distinguishing symptom of white-tip is the presence of leaves with white tips of 2.5-5 cm long. The tips of the developing leaves may be twisted and wrinkled and the flag leaf may be twisted near the panicle. The infected plants are generally stunted.

The nematodes are seed-borne, and are spread from one crop to the next in seed rice and stubble. They become active after rice is sown, and migrate towards the growing point of the young rice plants where the nematode feed and reproduce. Anywhere from 8 to 13 generations can be reproduced during a growing season. Feeding injures the developing leaves and panicles before emergence. Later on, the injuries are white, necrotic leaf tips and small, sterile panicles. Grain yields from diseased plants are markedly reduced.

Several methods can be used to control white-tip. Resistant seed varieties, nematode-free seed should be used in planting, re-cleaned seed lots free from shrunk and light-weight seeds can be used for seeding. Infected rice straw should be removed from the fields and burnt. Fall plowing and rotations also help control or prevent the spread of white-tip in rice.

Pests of Rice

Several pests frequently damage rice severely. Among them is the larva of *Dioptera* and *Orthoptera* which may cause severe injury by feeding on

young rice plants, particularly in rice grown in saline soils. Economically important population thresholds constitute 40 larvae per 1 sq. m.

The *tadpole shrimp*, *Triops* (*Apus*) *cancriformis* Schaft., although not an insect, is also a pest of rice. The adult, spherical shield-shaped shrimp, is about 3.0-3.5 cm long (Fig. 48). The eggs are ball-shaped, reddish-black and 0.4 mm in diameter and are laid by the female shrimp in water or soil. This gives the eggs shelter for many years after water is withdrawn. In the spring, 3 to 4 days after flooding the field, the eggs hatch and the young larvae or maggots, as they are commonly called, emerge to become fully grown adults in 14-15 days. The young larvae first feed on the organic matter, and within 8-9 days reach 7-10 mm in length. They then migrate to the rice and cause severe injury by pruning the young roots and shoots. Germinating seeds lying on the soil surface become easy targets for the maggots. The tadpole shrimp survives for one generation, and late in June, it disappears.

Since the immature stages are spent underwater among the rice roots, most of the shrimps larvae can be destroyed by draining the fields and allowing them to dry for a day or two. Appropriately leveled checks, timely opened drainage furrows and peripheral ditches are essential for rapid drainage.

Esteria (*lymnadia*), *Leptestheria* spp., a shellfish, is another aquatic pest of rice. Its body is enclosed in a bivalve translucent shell, and is 9-10 mm long and 4-5 mm broad, in fully-developed specimens (Fig. 49).

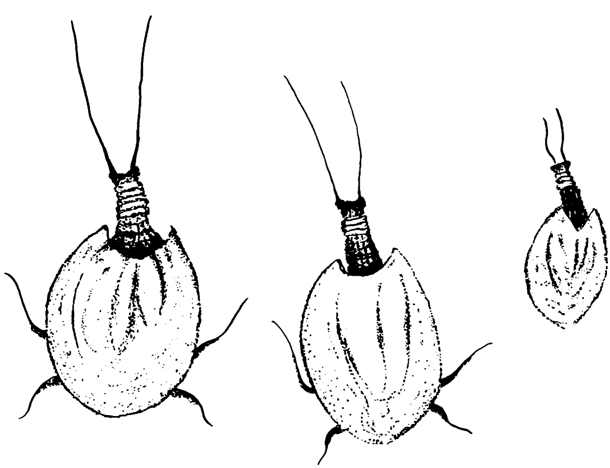


Fig. 48. The tadpole shrimp, *Triops* (*Apus*) *cancriformis* Schaft.

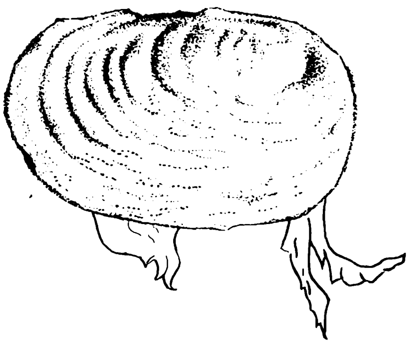


Fig. 49. The esteria (limnadia), *Leptestheria* spp.

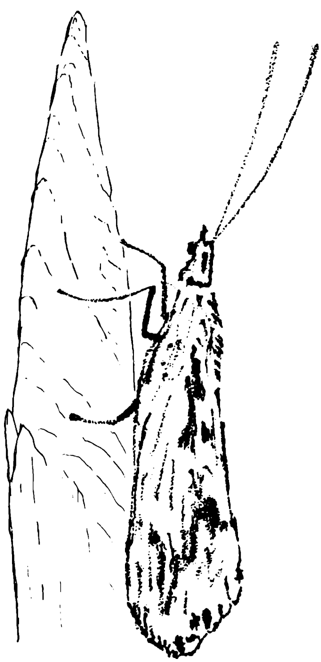


Fig. 50. The caddis fly, (Trichoptera), *Limnophylus stigma*

It moves with the use of its antennae and lays its eggs in a shell. Its white ball-shaped eggs are 0.13 mm in diameter and are dropped into water as they accumulate within the shell. The eggs settle on the soil surface, and

may stay there for years. Three days after the field is flooded, the eggs laid in the previous season hatch, and larvae emerge.

Esteria matures within 8 to 10 days, the first 5 to 7 of which are spent feeding on organic matter. Upon reaching maturity, the full-grown *Esteria* quickly migrates to the soil surface and begins to feed on the young rice plants. What ensues is the destruction of a significant number of these plants. The life-cycle of *Esteria* is one generation, and it can be found in rice fields until late June.

Draining and withholding water for 1-2 days controls larvae development by disturbing its life-cycle, thus eliminating the risk of injury to rice seedlings.

The *caddis fly*, (*Trichoptera*) *Limnophylus stigma*, is an insect pest of rice. Several species of this numerous insect order are present in the Far East and Central Asia (Fig. 50) injuring rice severely in certain years. The 10-16 mm long larva is what inflicts damage on the rice plants. The larva lives in the water enclosed in a cigar-shaped tube that it builds around its body from minute plant debris and trash. The tube size varies from 12 to 20 mm. The larva holds the tube fast on its body with its last body segment and moves about with its head and three pairs of thorax legs. The larvae migrate to rice fields and feed on rice seedlings, thus reducing the density of plant stands.

Draining the field for 1-2 days or treating it with chlorinated lime at a rate of 10-12 kg/ha helps control the caddis fly.

The *barley leaf miner*, *Hydrellia griseola* Fall., is a dangerous pest of young rice in the Far East, Northern Caucasus, and the Ukraine. A grey fly 2.5 mm long (Fig. 51), the miner usually infests rice fields in April and in the Far East in May. Its white eggs, elliptical in shape and 0.6 mm long, are laid on the upper leaf surfaces and along the veins of rice leaves that are afloat. Damage is done 2-3 days after the eggs hatch and the maggots appear. The miner maggots attack the leaves and feed on their parenchyma. This reduces the photosynthetic capacity of the leaves and consequently impairs the rice yield. The pale-yellow maggots are elliptical and 3.0-3.5 mm long. They pupate in the mines they have made in the leaves and develop pale-brownish pupa. Within 6-9 days they emerge as flies. The barley leaf miner produces 3-4 generations and attacks all rice seedlings regardless of the date of seeding.

Lowering the water or draining the fields for 2-3 days, or treating fields with a 20% emulsifiable methaphos at 0.2-0.4 kg/ha (active ingredient) provides reliable control of egg and larva population.

The *rice leaf miner*, *Hydrellia griseola* var. *scapulasis* Loew, is a destructive pest of rice in the Far East. The black flies are 3.3-3.8 mm long and lay eggs on the leaf tip tissue. They attack rice in June. The maggots

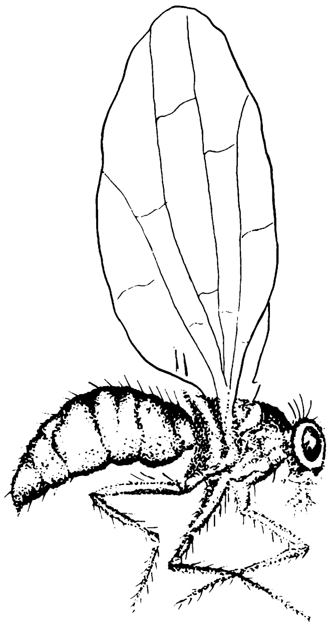


Fig. 51. The barley leaf miner, *Hydrellia griseola* Fall.

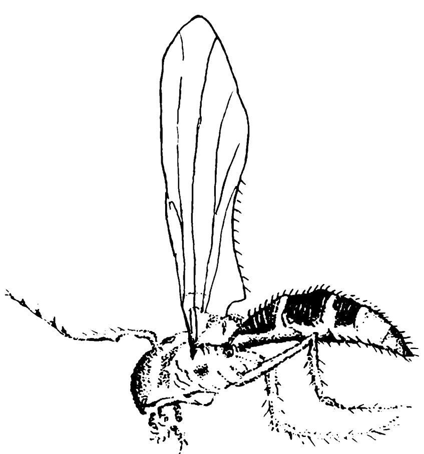


Fig. 52. The rice midge, *Chironomus* spp.

are yellow-green, 4-6 mm long when hatched, and feed within the leaf, working their way toward its base. The larvae pupate on the top of the

damaged leaf, which turns brown and lies prostrate on the water. Infestation leads to a reduction in yield. The rice leaf miner produces three generations of which the first two are most damaging to rice. Preventive measures include adequate weed control and proper water management.

The *rice midge*, *Chironomus* spp., is a destructive pest of rice in the Far East, Northern Caucasus, and the Ukraine (Fig. 52). Only occasionally does the insect infest rice in Central Asia. Light attracts the midge and can be used to determine when the midge is attacking the rice fields. Such attacks usually occur in April. The eggs, laid in water, hatch yellowish, translucent larvae within 2-3 days. The larvae first feed on organic matter and rice roots. During this time, the injury to the rice is insignificant. The adult larvae, 8 mm long, infest the lower surface of leaves that are afloat, and feed on the parenchyma. This causes the leaves to wither and reduces yield. The rice midge produces three generations and damages all rice seedlings regardless of the date of seeding. It is most damaging when the rice plants are excessively flooded and the leaves stay afloat for a long time on the water surface. Lowering the water level or draining the rice fields for 2-3 days provides effective control of the midge larvae. Treatment of the fields with a 20% emulsifiable methafos at a rate of 0.2-0.3 kg/ha by aircraft sprayers is also effective on large larvae populations.

The *shore fly*, *Ephydra macellaria* Egg., infests rice in almost all rice-growing areas. The fly is 4 mm long. Its thorax and abdomen are metallic-green, its legs, reddish-green. Its wings are large and translucent

Fig. 53. The shore fly, *Ephydra macellaria* Egg.

(Fig. 53). It lays about 80 to 90 eggs in the water covering rice checks. The larvae are what is destructive to rice, as they are adapted to live in water, where they feed on young rice roots. Such feeding results in the withering and reduced rice plant stands. The larvae pupate where they feed, i.e. on roots, stems and leaves, and emerge as flies within 8 to 12 days. The fly produces 3-4 generations. When larvae population counts are high, withholding water for a day or two may provide adequate control. Treatment of fields with 80% emulsifiable chlorophos powder at a rate of 0.8-1.6 kg/ha is also effective in controlling large larvae populations.

The *rice water weevil, Hydronomus sinuaticollis* Fst., is found in all rice-growing areas of the Far East and Central Asia. The adult weevil is black, 4-5 mm long, and has two light spots on the elytra (Fig. 54). The male water weevil is smaller than the female. In the post-feeding stage the larvae overwinter in the plowed-up soil at a depth of 5-8 cm. The larvae are milky white, legless, and about 7-8 mm long when fully grown. They pupate in the spring, and emerge as weevils in May or June. The weevil feeds on germinating seeds and roots of young rice. Rice that is sown late is usually more susceptible to the weevil. Eggs are laid in the root zone. The hatched maggots live first in the plant, and later migrate to prune the roots. Infested plants either die, or grow more slowly forming small panicles with poorly set kernels. Rotations, disking the stubble in the spring, fall plowing, and seeding at optimum dates help prevent and control the rice water weevil.

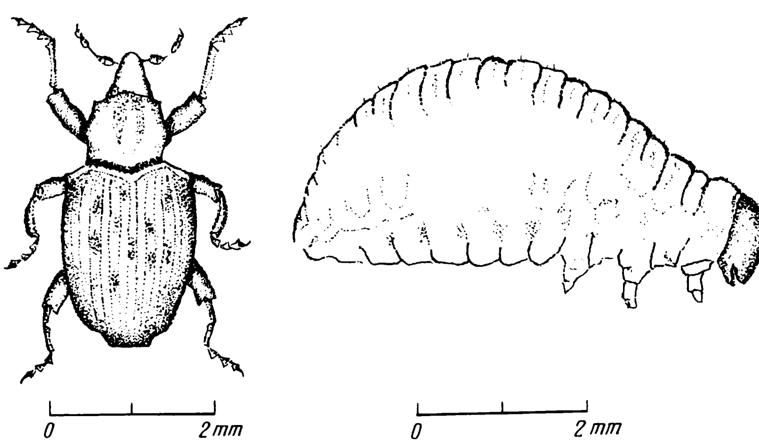


Fig. 54. The rice water weevil, *Hydronomus sinuaticollis* Fst., adult and larva

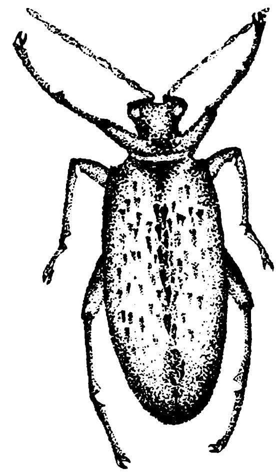


Fig. 55. The rice leaf beetle, *Lema suvorovi* Jacobs var. *oryzae*

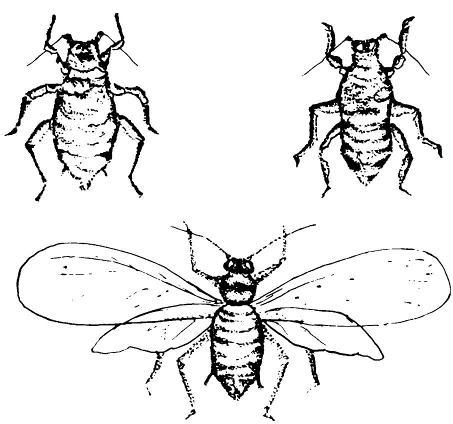


Fig. 56. Cereal aphids, *Aphididae*, winged and wingless

The *rice leaf beetle*, *Lema suvorovi* Jacobs var. *oryzae* is a widespread and destructive pest in the Far East. The bugs, 4-5 mm long, have blue elytra and yellow head and prodorsum (Fig. 55). They feed on rice leaves. The female bug lays chains of 6 to 12 eggs on the upper surface of the leaf in late May and early June. The eggs hatch and larvae emerge

which feed on leaves and in mid-June when they complete feeding, they pupate and emerge as bugs 10-12 days later. The rice leaf beetle produces two generations the first of which is the most damaging to rice. Bugs of the second generation spend the winter in the soil or in dry grass, straw and other material that affords them shelter. In the spring, then, they infest primarily the weed plants. Proper weed control and treatment with 80%-emulsifiable chlorofos at 0.8-1.6 kg/ha (in terms of active ingredient) reduces the number of bugs in subsequent season.

The *cereal aphid, Aphididae,* attacks rice in the Northern Caucasus, the Ukraine, and Central Asia. Aphids are most destructive to rice sown late in the spring on soils deficient in nitrogen. Some species are winged, others, wingless (Fig. 56). The economically significant level of infestation (population threshold) is 1-2 aphids per square meter at leaf-tube formation. The appearance of aphids in rice can be controlled by proper and timely weedings and treatment of fields with 20%-emulsifiable methaphos at 0.2-0.3 kg/ha (active substance).

Many other species of insects and various other pests infest rice fields by migrating to rice from the levees and weed growths. Feeding on rice is supplementary for most of them, so, if rice cultivation practices are adequate, the infestations seldom cause enough damage to reach economically significant levels.

Environmental Considerations in Rice Production

The types and rates of chemicals (insectofungicides, pesticides and fertilizers) used on rice should be determined with great care and caution to avoid losses by water drainage and leakage, and only where the non-chemical methods of weed, disease, and pest control prove ineffective or impracticable. Chemical means of plant protection are not recommended for use in the vicinity of areas which drain into the fish-growing bodies of water, rivers, reservoirs, and sources of potable water.

The general requirements for the use of fertilizers, insectofungicides and pesticides are as follows.

(1) Avoid the use of hexachlorcyclohexane (HCCH) and other chlororganic formulations to control rice diseases and pests.

(2) Strictly follow cultivation practices and recommendations on the use of herbicides.

(3) Avoid use of herbicide 3,4-D, such as propanil and surcopur on soils rich in organic matter (peat, peaty-gleye, humus-gleye).

(4) Prevent leakages and avoid draining of fields treated with: propanil for 15-20 days, with zineb, chlorofos, methafos and methatione for 20 days and with ordram and saturn for 30-40 days.

(5) Use fungicides and pesticides for the final treatment of rice fields not later than 20 days before harvesting, with care taken to avoid herbicide drift from the target area.

(6) Use, instead of herbicide, mechanical and other adopted methods to control grass weeds on irrigation structures (banks, delivery slopes, drainage ditches, etc).

(7) Use special facilities on the farm to store, and special closed delivery vehicles to handle to and from the farm mineral fertilizers either in bulk or in sacks to avoid losses from wind, draught, and atmospheric precipitation. They should never be left out in the open.

(8) Properly cover bulk fertilizers when delivering them to the rice fields. This avoids both wind losses (which sometimes amount to 2 percent) and contamination of the environment. Load the bins of drill-type or other types of fertilizer applicators and spreaders within the rice checks instead of in the road which usually borders the drainage ditches.

(9) Avoid drying the soil during seedling establishment. Drying facilitates nitrification, in which case ammonia nitrogen may convert into nitrate which since it is not fixed in the soil is easily leached with seepage waters.

(10) Apply basal nitrogen fertilizer not earlier than 2-3 days before seeding rice and cover the fertilizers at 10-12 cm by harrowing. When ap-

Table 12. Distance, m, to Herbicide-Susceptible Crops from Target Area

Herbicide	Target area	
	windward side	lee side
2,4-D, amine salt	1500	100
2M-4X, sodium salt	1500	100
2,4-D, ethers	2000	100
Propanil and analogues	500	100
Soil herbicides (ordram, saturn) for:		
soil treatments	300	50
crop treatment	500	100

plied by airplane, reduce the drift of fertilizer from the target area in every possible way.

(11) Avoid draining the rice fields during fertilization until all nutrients are absorbed.

(12) Regularly check the chemistry of recirculated irrigation water for salt nutrient and herbicide content.

(13) Protect crops susceptible to herbicides and grown relatively close to rice fields by providing the airplane operator with on-ground indicators of the distance between these crops and the target areas (see Table 12).

The harvesting of mature rice and post-harvesting operations are important aspects of rice culture. Rice crops usually mature later in the season than other grain crops. The time to harvest rice therefore varies from early September in the European USSR to mid-September in the Far East. For the best results harvesting should continue for no more than 20-25 days. Delaying or extending the time of harvesting increases losses, reduces both yield and grain quality, and does not provide enough time to adequately prepare the land for next season's crops.

Factors that determine the duration of the harvest are the time and date of seeding, the maturity period of the rice variety, the level of infestation, soil and drainage conditions in the rice fields, and the weather before and during harvesting.

Draining for the Harvest

Draining at the proper time before harvesting is required to sufficiently dry the soil to use the heavy rice-harvesting machinery. It is, however, equally important to maintain the water in the rice field long enough to permit the rice crop to reach proper maturity.

When to drain depends on the soil type, drainage facilities, and weather conditions in any given season. Some soils dry quickly, others slowly. Rice growers soon familiarize themselves with the time to dry their soil, and soon learn to judge when the best time is to drain the fields for harvesting without letting the rice crop suffer from a lack of soil moisture. In a year with a typical amount of heat and rainfall, the date when rice will be ready to cut can be estimated by observing the date of flowering and initiation of heading. Rice normally requires 40 to 50 days from flowering to maturity.

The flow of water into the checks is usually reduced by the time rice reaches the soft-dough (milky) stage, and is discontinued altogether when the rice matures to the hard-dough (waxy) stage so that the water will recede slowly at a rate of 1-1.5 cm per day. Where the soils are saline, the fields are drained. The level of groundwater should preferably be maintained low through proper drainage to avoid waterlogging the checks. Less time is required to dry the soil where drainage furrows have been opened in the spring. In fields without drainage furrows, pools of water are likely to appear. In such cases, the water is either pumped out or removed through hand-made furrows.

Usually riceland may be drained when the rice crop has fully headed and the panicles have turned down, and ripened in the upper parts. This stage normally occurs about 2-3 weeks before the rice crop is ready to harvest.

Water intake should be discontinued progressively beginning with the low-lying checks that are usually downstream from the headwork, then successively with the checks at higher elevations. This results in a simultaneous and uniform drying of the paddies in each large check. By the time the rice crop is ready to cut, the soil should be dry enough to support the harvesting machines and equipment.

Premature drying of the field checks will delay the filling of grain, so the rice crop harvested too early will have a greater quantity of immature, empty and poor-quality grains, and will produce a smaller yield of head rice at milling. On the other hand, it is equally important not to miss the time of maturity. When rice stands too long in the field, losses are increased due to lodging, premature germination in the panicle, and shattering.

Pre-Harvest Chemical Drying

The pre-harvest application of chemical desiccants is a frequently used practice to speed the drying of rice in the field before harvest. Of all the known materials applied as sprays, a 60% magnesium chlorate water

solution has proved the most effective when it is used at 25 kg to 150 liters water per hectare. After treatment with this desiccant, about 2-3 percent grain moisture and 4-6 percent leaf moisture is removed daily. Within 4 to 6 days, as soon the grain moisture content is brought down from within 20-27 to 15-16 percent, the rice can be harvested.

The aerial application of desiccants gives best results when carried out on clear bright days, early in the morning or afternoon. Average diurnal temperatures should be about 9-10°C with a maximum wind velocity of 4 m/s. Very good results are obtained if there is no rain for about 6 to 8 h after spraying. The application of chemical desiccants at optimum dates (when 85-90 percent of kernels are fully mature) increases the grain yield, improves the seed quality, and reduces both labor and harvest time by 10 to 15 days. Rice treated with desiccants is usually harvested by direct combining.

Chemical materials used as desiccants should be considered poisonous, so no grower should use a desiccating chemical on the maturing rice crop until he has checked its legal status with reference to chemical residue tolerances. When used with caution, however, desiccants can give good results without the traditional aftereffect such as a drop in milling quality, kernel dislocation, and an off-flavor that may, occasionally, be imparted to the rice.

A new method of speeding up the drying of rice has recently been proposed by Professor E. P. Aleshin [8], and has proven effective in improving harvesting conditions and grain quality, and in reducing harvest losses. It relies entirely on a solution of water-soluble phosphorus fertilizers plus small amounts of 2,4-D amine salt, which is applied as a topdressing on rice in the milky stage of ripening.

Pre-Harvest Operations

After the irrigation water has been withheld and the soil is sufficiently dry, the rice around the check's border is cut with either a self-propelled crawler-mounted reaper, a combined harvester-thresher, or a crawler-mounted swather. This is done 2-3 days before the all-out harvesting of the rice begins in the fields enabling more time for the soil to dry out and the rice to mature, as well as eliminating the risk that the harvesting machines will run onto hydraulic structures, invisible to the operator.

Square-shaped rice paddies and large checks are divided into strips 50 to 70 m wide by cutting swaths from one end of the field to the other. Two cross swaths are cut from both sides of the field to provide a 6 to 10 m wide headland for the harvesting equipment. This increases the efficiency

of the harvesting machines by about 15 to 20 percent, reducing hand labor, and field losses.

The time to harvest food and seed rice can be determined by observing the date when 85 and 95 percent of the grains in the respective panicles are fully mature. If the crop is left in the field until it is overripe, the kernels may check (develop fine cracks). This will cause breakage during combining and milling, and a reduction in the yield of whole kernels (head rice). Biological yield losses from harvesting delayed by three days amount to about 0.2 t/ha. The losses rise to 0.5-1.0 t/ha when harvesting is delayed by 10 to 15 days. It follows that the prime time for cutting the rice crop should not be missed by the grower. Any delay will result in reduced yield due to shattering during hot, dry days and slow threshing if the weather is humid and cool.

The time to harvest depends largely on the weather. The mid-season varieties of rice (Kuban 3) which are sown about the same date should be harvested within 8 to 10 days, and the late rices (Krasnodarsky 424), within 10-12 days. It has been established that standing rice does not hold its maximum yield for long. In the Kuban river riceland, for instance, rice keeps its optimal grain yield (to within ±5 percent of the maximum) only 8 to 10 days.

Harvesting Rice

Most rice in the Soviet Union is harvested mechanically either with self-propelled combine-harvesters, or with a tractor-drawn header or swather which threshes from the windrow. Harvesting by hand may be resorted to only on very small acreages when the weather is rainy and the use of harvesting machines is impractical.

Direct combining, or single-phase harvesting, and separate, or two-phase harvesting are the two major methods to harvest rice in this country.

Over 80 percent of the total rice acreage in the USSR is harvested by the two-phase method. Essentially, this is cutting the rice with a swather or windrower, and threshing it from the windrow with a pickup combine when the grain is adequately dry. The rice is then dried artificially before it is stored or milled. Careful adjustment of the reaping machine and the thresher leads to grain of a high milling quality and market value.

The two-phase method permits rice to be cut at earlier dates, followed by threshing from the windrow 3-5 days after. This results in grain with much less moisture content, thus reducing the cost of artificial drying. If the rice crop is left in the windrow too long, the grain may check (crack)

increasing breakage during threshing and milling, and markedly reducing the yield of head rice and the quality of seed rice. It is therefore better to thresh from the windrow at the proper time and avoid large intervals between cutting and threshing.

Direct combining or combine harvesting is more efficient and economic in that it provides grain of the highest milling quality and considerably reduces field losses. It is more effective over the two-phase method, particularly when the weather at harvest time is unstable, because it permits rice to be removed from the field in one operation with no danger of weather damage. Hopefully, with improved combines along with a wider use of desiccants, grain driers, cleaning facilities and less lodging rice varieties that produce less vegetative growth, direct combining will find a wider application in the near future.

Already in some rice-growing areas, self-propelled rice combines provide the major means of harvesting rice.

With either method, obtaining a control yield of threshed grain by cutting and threshing 2 swaths in 2-3 representative (typical) field checks or rice paddies has become an important practice in all rice-producing areas. Practical observation confirmed by growers' results indicate that the operator is the most important factor in preventing high combine losses. Therefore, control threshing is usually done first by highly skilled combine operators who determine for the other operators where to adjust the thresher device in the combines, and the cutter head in the swathers and reapers.

Fig. 57. Cutting rice with a front-mounted swather

With the common two-phase harvest method, rice is cut with a tractor-mounted side-delivery windrower or reaper. Front-mounted swathers having two active cutter-bars are good for cutting badly lodged rice (Fig. 57). A header or windrower is also suitable in such cases as it delivers uniform windrows from 4.5 to 5 m wide swaths. Such windrows dry quickly. Self-propelled headers or swathers with the knife-divider removed and the reel adjusted to the rear shield of the frame can also be successfully used to cut rice crops that are badly lodged. These adjustments reduce the number of cut out panicles, lower losses by reel shattering, and improve the operating condition of the reel and the delivery chain. The cam-action reel should be adjusted 200-250 mm frontwise relative to the cutter so that the rake just touches the plant stem at 2/3 of its height from the base. The reel is adjusted in level with the cutter-bar to cut lodged rice below the point of bending, i.e. 50-70 mm from the top so that the reel rake then only cleans the knife and pushes the cut plants onto the delivery chain. The reel speed should always exceed the ground speed of the swather. This effects proper reaping at 15-20 cm from the ground surface and minimizes field losses. The height at which the rice is cut is very important because the proper amount of straw serves as a cushion to the grain during threshing, resulting in a lower cylinder loss and less breakage.

Rice in a paddy or large check may be cut either by the strip or by the continuous method. With the first method, each swather or combine works a strip of rice crop 50-70 m wide. It starts on one of its longer sides, makes a 90 deg turn at the corner and an idle run along the shorter side of the strip to turn again and cut rice along the other longer side in the opposite direction, working clockwise from the check's field margin towards the center line of the strip.

Strip harvesting is good for harvesting field checks where the swather can pass over the levees from one rice paddy to another. The efficiency of the harvesting equipment is 15-20 percent higher, as the idle-run distance on the head-land is considerably reduced. The method is usually used for cutting badly lodged rice, or under extremely muddy conditions when turns are difficult to make due to large clods on the headland.

The continuous method is effective where soil is more dry and rice is not lodging. The method requires no headland as the harvester cuts the rice going counterclockwise along the check and makes a turn to the right (270° loop) each time it reaches a field corner.

Usually several harvesters form a group that completes harvesting a field check within 3-4 days (15-20 hectares per each swather). The group method permits the rice crop to be quickly cut and threshed with a pickup

Fig. 58. Group of combine harvesters threshing grain from the windrow

combine as soon as the windrows are sufficiently dry. Where the harvest time is late August and early September and the days are warm and dry threshing from the windrow is normally begun 3-5 days after cutting (Fig. 58). Where the harvest time is late September and early October the interval between cutting and threshing may be longer. Threshing from the windrow may not begin until the grain (not the stem) moisture content reaches 16 to 20 percent. Field observations confirmed by grower's reports indicate that if rice is left in windrows until overdried, this results in grain of poor quality creating heavy losses during threshing and milling.

The threshing operation in a field check 15 to 20 ha in size is also done by a group of 4 to 5 pickup combines. They are assisted by tractor-drawn or self-propelled grain carts which haul the threshed grain from the combine to the field-side trucks, who, in turn, haul the grain further to the driers or the elevator. With an average efficiency of 3-4 ha per combine such a harvesting team may complete a field check in 2-3 days. In both methods total field losses can be minimized and grain quality improved by threshing the rice straw with unthreshed grain a second time. Double threshing requires that 85 to 95 percent of the grain be threshed during the first threshing round while the remaining grain is threshed during the second round with a pickup combine harvester. The combine thresher should be adjusted so that no threshed grain will go into the new windrow as the straw leaves the combine. The windrows should be uniform in shape and not too large so that they do not crowd the feed. The more straw is fed, the higher the cylinder losses, particularly if the grain's moisture con-

tent is excessively high. Because the rice kernel is susceptible to cracking, the cylinders should be run at a slower speed than usual for small grain crops.

To obtain maximum grain yields it is necessary for the cylinder and the concave to be in good condition and for the concaves and other parts of the combine to be properly adjusted. The major combine losses are attributed to the cutter-bar, cylinder, rack, and cleaning shoe. Other losses may be due to overloading or improper machine adjustment, or a combination of the two. Overloading as a result of excessive ground speed is usually a major cause for heavy loss in all types and sizes of combines. Modern combines can be adjusted to do a good job of threshing with a minimum of shelling and cracking of the grain.

With a lath-reel pickup grain losses are about two times less than with the pegged-reel version of the pickup attachment. For this reason the lath-reel pickup is preferable to the pegged-reel pickup. High losses of unthreshed grain usually result from either improper cylinder (drum) or concave adjustments, or both. Losses of threshed grain may also come from poor separation in the straw wakers and cleaning shoe. Several tests should be made with each machine to determine the effect of adjusting or changing the ground speed. Cylinder speed should be varied with the rice varieties and the grain straw moisture content (Table 13).

Reducing the cylinder speed helps minimize shelling and cracking of the grain, but may increase the loss of unthreshed grain. For the second

Table 13. Combine Cylinder Speed for the First Round of Threshing, rpm

Variety	Straw condition	Threshing from windrows		Threshing by direct combining	
		peg-tooth cylinder	raspbar cylinder	peg-tooth cylinder	raspbar cylinder
Krasnodarsky 424	Dry	500-580	650-760	670-720	870-910
	Moist	580-630	760-810	720-760	910-980
	Wet	630-670	810-870	760-800	980-990
Kuban 3	Dry	580-630	750-830	700-740	900-950
	Moist	630-670	830-870	740-760	960-980
	Wet	670-720	870-940	760-800	980-990

round of threshing, the speed of the fan and cylinders should be greater than the rated one by 20 percent.

Rice harvesting machines include various tractor-driven swathers and reapers, self-propelled headers and windrowers, and self-propelled combined thresher-harvesters equipped with crawler tracks, half-tracks or tyres. In rainy seasons wide mud cleats may be bolted onto the tracks to increase support to the harvester. Other tractors and combines are equipped with tyres with mud lugs or cages, so that they can be operated on the sloping levees, and under extremely muddy conditions.

The rice farming machines usually operate by either the traction or floating principle. By the first, the tracks or tyres penetrate the muddy tilth to reach the hard pan on which they find a firm support for traction. By the second principle, machines have to move by flotation, acquiring support on the top muddy soil with the help of cage wheel or track extensions (extendable lugs). Ricegrowers would very much appreciate special self-propelled rice combines equipped with the "rice special tyre". Some self-propelled harvesters are equipped with large bins or hoppers for collecting the threshed grain. The hoppers are emptied by mechanically augering the rice into self-propelled "bankouts" or tractor-driven carts that take the rice to trucks which wait alongside the field. The rice is then hauled to driers or to aeration bins where it is unloaded by use of grain augers or other bulk-handling means.

Grain Moisture Content

Because the grain moisture content varies with the time of day, the combine threshing parts should be re-adjusted several times during the day: at 9-10 a.m. and 6-7 p.m. for the wet straw, and between 12 and 4 p.m. for the dry straw.

Rice must be of high milling quality to command a premium price, and to obtain this high quality and maximum yields, rice must be cut at the proper stage of maturity (moisture content).

When the rice crop has reached the proper stage and grain moisture, harvesting should proceed quickly because the loss of moisture in standing rice can be very rapid. If rice is harvested at the proper stage, the grains are fully mature in the upper portions of the panicle and are in the hard-dough stage at the base of the panicle. Observations indicate that maximum yields of head rice were obtained when rice was harvested at a moisture content of about 18 to 24 percent and then immediately dried to 13 and 14 percent. Varieties differ as to the range of moisture content at

which they yield the best quality milled rice. This range is rather wide, varying from 16 to 25 percent for some varieties. Many rice growers determine the moisture content of hand-harvested samples of their rice with various types of moisture meters before they begin all-out harvesting.

Thus, when harvesting for maximum quality, a lot of factors must be considered, but moisture content of the grain at harvest time is among the most important. Good results may be obtained with the use of chemical desiccants which hasten pre-harvest drying of the crop, if applied timely and properly.

Post-Harvest Operations

Straw Removal and Use

Post-harvest tillage and preparation for the next crop require that the rice fields be cleaned of rice straw and other plant residues. The straw can be removed from the fields after it is bailed; picked up and stacked off-field to be processed for animal feed. Some other suggested uses are as bedding, construction material, for manurial purposes or as a mulching material for purpose of soil protection. The straw can be removed from the fields either as the harvest proceeds or immediately after the harvest. For soil mulching, the straw is simply cut in the rice field with special straw spreaders or choppers and the straw particles are then spread uniformly over the stubble to facilitate plowing under with a disk plow. Some combines are now equipped with straw spreaders that cut up the straw as it leaves the combine. Various other machines such as straw rakes, pickup choppers, stackers and loaders assisted with special tractor-driven straw carts are used to facilitate the operation and haul straw stacks from the fields.

Processing Rice for Storage and Milling

The cleaning and drying of rough rice is very important for safe grain storage. Timely and proper processing of the field-run rice usually results in attaining grain of the highest quality and commercial value with lower input per unit volume of rice dried and stored. The post-harvest procedures include pre-cleaning, or scalping, drying and grading of the rough rice. Usually the rough rice coming from the field, unless the fields are

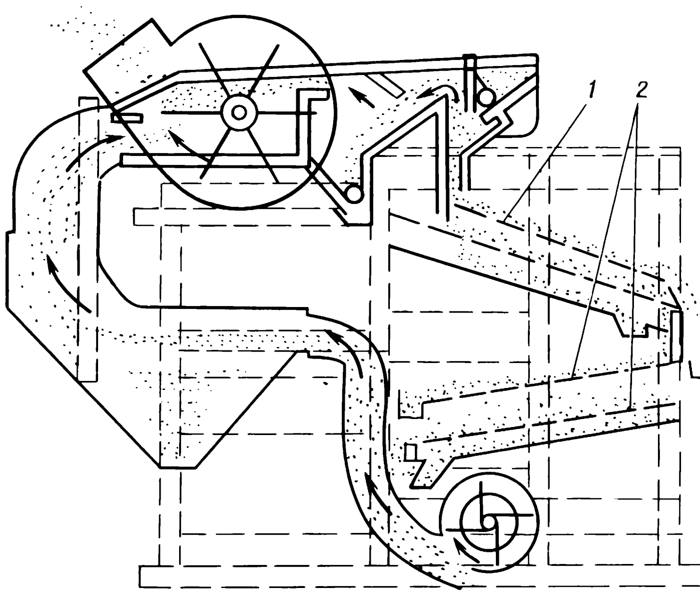


Fig. 59. A fanning mill
1 — feeder screen, *2* — cleaning screen

"clean", contains considerable foreign material, such as stems, weed seeds, and trash. It is therefore advisable to clean it partially with a scalper-aspirator machine before putting it into the bin for aeration. In some areas facilities and conditions may require that the rice first be dried. Such drying may require that the rice be passed through the drier several times. Frequently, the rice is also aerated between passes to remove foreign matter and light-weight, immature grains before it is put into storage.

Preliminary cleaning of rough rice can be done on the on-farm facilities that should include a fanning mill (Fig. 59) with a wind aspirator to remove light grains, hulls and other light-weight foreign material, a screen with large perforations to remove any remaining sticks, stems, lumps, and large weed seeds; and a finely perforated screen to remove fine broken rice grain, small weed seeds, and other small particles of foreign material. The pre-cleaned rice is then put into bins for aeration.

Aeration is the procedure used to cool and ventilate grain during storage to improve quality and prevent spoilage. This can be accomplish-

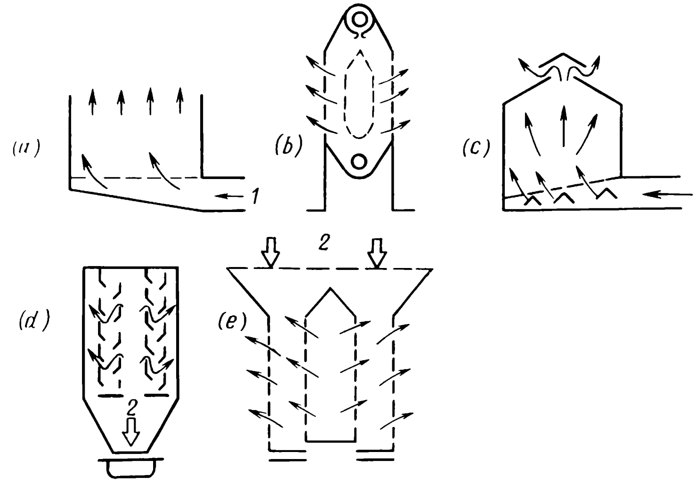


Fig. 60. Types of grain drier

1 — air flow, 2 — grain flow, (a) tray drier, (b) chamber drier, (c) storage drier, (d) louvre drier, (e) column drier

ed by turning the grain at regular intervals, by transferring it from one bin to another with a grain loader or grain thrower, or by circulating air through the stored grain.

For proper drying, moisture must be removed from inside the rice kernel. Drying too fast can result in internal cracking or checking of the kernels. To prevent this, drying is usually done in several stages with the moisture reduced only about 2 percent at each drying. After each stage, the rice is tempered in a bin so that the kernel moisture will equilibrate.

Conditioning the rough rice is done in a bin, although the term "bin drying" refers to drying in storage. Normally the grain is dried in the same bin in which it is stored, and this suits the method to the on-farm facilities. Bin drying sometimes consists in drying with unheated air. It is, however, often supplemented with artificial heat when necessary to accomplish drying within a specific time to prevent spoilage (Fig. 60).

To achieve rice of standard quality it may be necessary to put the rice through the cleaner a second time to remove less easily separated material, such as shelled rice grains and weed seeds, or light-weight and immature grains. The second step in rice cleaning is the *length separation* that removes any shorter-length grains (broken and hulled) with an indented cylinder type machine, and the *width separation* that removes any large-diameter grains with a screen or a perforated cylinder grader.

Rice is grown primarily for its starchy grain, which constitutes a high-calory dietetic human food product. The Soviet Union's growing movement towards more rice production has one goal above all: to obtain an end product of the highest standard. All varieties that are established as commercial rices in the country must meet the adopted standards for marketing, milling, and cooking (and processing) qualities.

Rice growers, of course, wish to obtain rice that will sell profitably. The market value of rice depends on variety, type of grain, cultivation methods, percentage of dockage, grain moisture content, and environmental and other factors.

The milling quality of rice is based on its head rice yield since head rice is usually the milled product with the greatest monetary value. The yield of total milled kernels (head rice and all sizes of broken kernels) is important too. This yield is influenced by the proportion of hulls (huskiness) and the amount of fine broken kernels which are unavoidably included in the bran fraction during the milling process.

To command a premium price rice must have good cooking and processing qualities which historically are associated with specific grain types of rice. Rice varieties differ significantly in all these qualities.

Among other characters that determine the dietetic, energy and digestive values of rice are the flavor (odor) and color, amount of protein, content of amino acids and fatty acids, mineral matter, vitamins and other chemical characteristics that depend on the variety, environmental factors, cultivation methods, and drying and storing conditions. Of the totality of quality variables marketing, milling, and cooking qualities of rice are the most important.

Marketing Quality

The market value of rice, which is invariably associated with its milling, cooking and processing qualities can be improved through drying, cleaning and grading the field-run rough rice, and includes established stan-

dards for grain moisture content, dockage, 1 000-grain weight, amount of yellow endosperm grains, and red rice content.

The grain moisture content is usually connected with marketing characteristics and safe storage parameters, and determines the rate of the biochemical and microbiological processes which occur in the grain. A moisture content above 15 percent usually leads to grain heating, mold growths, yellowing of endosperm, irreversible changes in the grain chemistry, and a reduction in the milling yield of head rice. High moisture content also deteriorates the cooking quality, the more so, the higher the moisture and ambient temperature.

The dockage, used to classify the marketing quality of rice, includes all foreign matter of both organic and inorganic origin (mud lumps, pebbles, spikelet and floral glumes, empty spikelets, awns, etc.) and broken and hulled rice grains. High dockage reduces the market value of rice and increases the cost of cleaning. Foreign material frequently has a higher moisture content than the grain, and this may cause spoilage.

The 1 000-grain weight can be used as a physical parameter to characterize the rice's marketing quality, and may, to a certain extent, be related to the milling quality of rice. The 1 000-grain weight was formerly closely associated with the milling characteristics of rices. However, recent investigations have shown no appreciable correlation between grain mass and milling yield. It has been proved that both the well-developed and the underdeveloped or immature grains are about equal at milling as regards huskiness, mealiness, yield of head rice, and percentage of the various sizes of broken milled kernels.

The yellow endosperm grain content refers to the dockage and is used to classify the market value, or grade of rice. Yellowing of the endosperm is a result of irreversible biochemical and chemical changes within the grain due to poor storage. The grain with yellowed endosperm differs from the standard white endosperm grain in chemistry and protein quality. It contains more total nitrogen, mineral phosphorus, sugars, and has less sucrose and organic phosphorus. In addition, it shows a higher resistance to milling. The percentage of such grains in rough rice may vary from 0.5 to 5, although their amount may occasionally reach 10 to 15 percent.

The red rice grains are undesirable forms of *Oryza sativa* in which seed and fruit glumes are red or reddish-brown. Milling removes these glumes and gives the kernel a white color, but insufficient milling may leave colored streaks that render cooked rice reddish. To improve the market value, rice lots with a certain amount of red rice are usually given more polish.

Milling Quality

Huskiness, which leads to total losses in milling, has been used to classify the milling quality of rice. The higher the percentage of hulls removed, the lower the milling yield. Because huskiness is associated with the structural and mechanical characteristics of the grain, a slight change of about one percent in huskiness, which includes the bran and the polish, changes the total yield of milled rice by about 1.5-2 percent. Losses in milling the domestic rices vary on the average between 18 and 19 percent, although the variation may be greater, and reach as high as 16 to 22 percent. The hulls have no food value but are successfully used in hydrolysis processes for the production of feed yeast, furfural, and other useful products.

The checking of rice, or fine cracking, is usually used to characterize milling quality. Unlike most cereals, rice is consumed as unbroken kernels, so the market value for whole grains is much greater than for broken kernels. Checking in rice is attributed primarily to the low elasticity and poor mechanical strength of the grain, and depends basically on drying. The percentage of checked grains varies greatly from 5-10 to, sometimes, 60 and 70. The number of micro- and macro-cracks in the grain may also vary from 1 to 4. A one percent increase in checking reduces the yield of head rice by 0.2-0.5 percent.

Vitreousness is an important measure of the milling and cooking qualities of rice. Usually, it varies between 95 and 98 percent. The more vitreous the grain, the less breakage during milling and the more flaky and non-sticky the rice when cooked. The longitudinal location of the mealy spot along the edge of kernel is preferable for milling as it gives good vitreous head rice.

The grain type characterized by the grain measurements (length and width) is generally associated with specific cooking and processing qualities. Varietal exceptions, though, exist within each type of rice (Fig. 61). With a rare exception the domestic rices refer to the short-grain type with a length/width ratio 1.6 to 2.0 (Table 14).

The smaller the ratio, the higher the milling yield of head rice. The long-grain rices are highly esteemed because of their high cooking quality, although the yield of head rice of the long-grain rices is appreciably low.

Yields of head and total milled rice are the basic characteristics of milling quality for different types of rice. Yields of head rice may vary widely depending on variety, grain type, cultivation practices and post-harvest methods of processing. Generally, average yields of total milled rice and head rice vary with the variety from 60 to 75 and from 50 to 95 percent, respectively. The yield of total milled rice of most domestic varieties

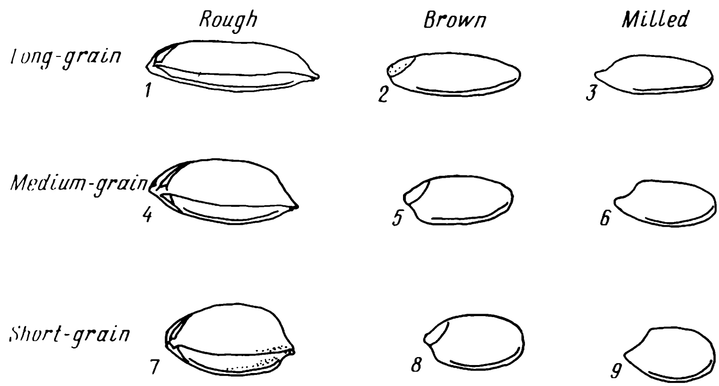


Fig. 61. Grain form and dimension (L, W, mm) for different types of rice

1 — L = 9.1, W = 2.4; 2 — L = 7.0, W = 2.0; 3 — L = 6.6, W = 1.9; 4 — L = 7.8, W = 3.1; 5 — L = 6.0, W = 2.7; 6 — L = 5.6, W = 2.4; 7 — L = 7.2, W = 3.6; 8 — L = 5.4, W = 3.0; 9 — L = 5.0, W = 2.8

Table 14. Types of Rice According to Length/Width Ratio

Grain type	Length/width ratio		
	rough	brown	milled
Long-grain	3.8	3.5	3.4
Medium-grain	2.5	2.2	2.3
Short-grain	2.0	1.8	1.8

ranges from 69 to 72 percent of which 75 to 98 percent are head rice.

The objective of rice milling is the removal of hulls, bran layers and germ with a minimum of endosperm breakage. The milling process generally includes four basic operations: (1) cleaning the field-run rough rice to remove mud lumps, rice stems, leaves, weed seeds, weed stems, and other foreign matter; (2) shelling the cleaned rice to remove hulls to obtain brown rice; (3) scouring the brown rice to remove the coarse outer layers of bran, white inner bran and aleurone layers, and germ; and (4) grading the mixture of whole and broken kernels according to the follow-

ing classes: *head rice* (whole-grain milled kernels), *second head* (larger pieces of broken milled kernels), *screenings* (finer pieces of broken milled kernels), *brewer's rice* (very fine pieces of broken milled kernels).

Cooking Quality

Most of the domestic varieties of rice are called common food varieties, i.e. they have no distinctive flavor or odor when cooked, and the starch in the endosperm contains both amylose and amylopectin. There are, however, other kinds of rice — glutinous or waxy with only amylopectin in the endosperm starch. No aromatic or scented rices are grown in the Soviet Union.

As was mentioned earlier, rice varieties differ in cooking and processing qualities. The quality of cooked rice depends on grain type and may vary from sticky to flaky. The short-grain rices are more moist when cooked and are used for such products as dry cereals. Fully cooked grains of typical short-grain varieties are somewhat split, relatively firm yet tend to stick together. Typical long-grain varieties usually cook to a flaky state with a minimum of splitting and show no tendency to stick together. Some types are used for specific processed products. Although each grain type is generally associated with specific cooking and processing qualities, some varietal exceptions exist within each grain type.

Other terms used to describe cooking quality of rices are water uptake (moist or dry), soft or firm, and mealy or chewy. Since different cultural groups prefer different textures there is a demand for all types of rice for use as home-cooked table rice.

There is also a demand for all types of rice for use in different prepared products. A considerable amount of each rice crop is processed into various kinds of prepared foods, such as quick-cooking rice, breakfast cereals, canned rice, canned soups, canned rice and vegetable mixtures, dry soup mixtures, enriched baby foods, etc. Rice flour is used in various processes, and broken rice is often used in brewing.

The wide use of newly released varieties and proper seed production from breeder and foundation seed to the growers' seed stock on the farm are essential for high-level rice production with minimum input. New and superior varieties, however, can make their contribution to practical agriculture only if the seed reaches the farmer in varietally pure state, in adequate quantities, in an undamaged condition, free of weed seed, and at a reasonable price.

The general purpose of seed production is to increase those old and new varieties which are superior to standard varieties for commercial distribution. The production of seed rice consists of growing the primary seed, called "foundation seed", and then increasing this seed in sufficient quantities to meet the request of the practical farmer for his seed stock supplies. To produce high-quality seed, a grower must have a superior seed source of a well-adapted variety. Formerly, each farm would obtain a certain amount of such seed and multiply it to establish its own seed stock on the farm. But today, modern harvesting and processing methods, bulk drying and storage have increased the possibility of seed mixing. This led to the need for sources of pure seed. As a result, the seed certification program now in effect in this country is an important part of rice production.

Sources of Pure Seed

Production of primary seed is carried out by institutions for rice research and their experimental stations and farms. They produce foundation seed (super-elite and elite) and multiply promising varieties for release to the growers. Production of farm seed stock is done largely by the commercial grower who breeds foundation seed through three generations, the third of which is sown for commercial grain output.

Classes of Seed

The classes of seed, termed breeder, foundation and certified seed, can be described as follows:

(1) Breeder seed is seed directly controlled by the plant breeding institution, and is the source of select seed handled at selection nurseries for the production of seed of the certified classes.

(2) Foundation seed is the progeny of breeder or select seed handled at seed increase nurseries to maintain specific genetic purity and identity. Foundation seed is usually the first-year increase from breeder seed. It is produced on fields that have not grown another variety or a lower class of the same variety during the 2 previous years. The distribution of foundation seed to growers usually is handled through specialized seed production farms and/or stations under a breeding center that increase this seed to the commercial growers as a certified class seed. For new varieties or for old varieties in short supply, specified amounts of seed may be increased or reduced depending on demand.

(3) Certified seed is the progeny of breeder, and more so than foundation seed is handled so as to maintain a satisfactory level of genetic purity and identity. It is produced in riceland areas specifically allotted for seed increase purposes. The production and certification of seed is not a part of the breeding program.

The super-elite and elite seed is distributed to growers to be increased to quantities sufficient to maintain a seed stock necessary to satisfy the grower's needs. Usually, the third-year increase from certified or foundation seed is used for commercial grain production. Thus, seed of a commercially established variety is renewed once in three years. For the production of the various classes of certified seed it is necessary to have clean land and to prevent mixtures in seeding, harvesting, and processing. The careful tending of all fields to remove undesirable weeds, other crop and off-type plants may increase the production costs, but is very essential.

Seed Rice Culture

Varietally pure, high-quality seed in a viable condition can be obtained only through the proper use of the whole spectrum of agronomic practices. This includes adequate seedbed preparation, crops grown preparatory to seeding rice, the use of high-quality seed, optimum dates and methods of seeding, adequate fertilization, and, finally, proper mechanical treatments (threshing, cleaning and grading). Practical ex-

perience has indicated that seed rice grown in good soil that receives the best fertilization and cultivation treatments is usually larger in size than seed of the same variety grown in poor soil and inadequately cultivated. The higher the level of cultivation, the slower the process of varietal deterioration under commercial farming. Strict observance of the seed production cultivation requirements usually results in seed with high varietal and field qualities which will be preserved well in the 5th, or even 6th, generation. Any retreat from the established seed-rice cultural requirements may bring about a rapid deterioration in the quality of even the first-year seed. This will undoubtedly reduce the grain output of table rice in the area.

Usually, the fields where rice will be grown for seed are treated much better than the commercial rice paddies to benefit the rice grower with seed rice of high standard. To avoid mixing, each variety is sown with a separate clean seeder. The results of rice research and advanced practice indicate that perennial grasses, cultivated fallows, and new lands developed for rice are good for seed rice production. The land should be thoroughly worked to a fine tilth and adequately fertilized. Saline lands are considered inadequate for seed production and should be avoided. The irrigation and drainage facilities should be operable and in good shape, and the land leveled to allow rapid flooding and draining if necessary.

The best time to sow rice for seed is when the soil temperature at a depth of 3-5 cm is 14 to 16°C, which for most rice-growing areas occurs in late April and early May.

To obtain a high germination rate the seed, usually kept cooled during storage in the winter period, is aerated and warmed up either in grain bins or grain driers, and treated with granosan M 2-3 weeks before seeding.

The rate of seeding depends on the variety and may vary from 4.5 million to 6 million viable seeds per hectare. Where the elite seed is being increased for commercial release, the rate of seeding is reduced to 1.5 million viable seeds per hectare. Good results can be obtained by drilling 3 million viable seeds per hectare in rows spaced at 30 cm. This method has proved effective for rapid multiplication of new and promising varieties since under such a wide-row method of seeding the multiplication coefficient increases enabling the grower to achieve higher yields at a much lower rate of seeding. Under this method, a rate of 100 kg viable seeds per hectare gave 7.16 t/ha of seed rice according to the USSR RRI data.

The wide-row method of sowing rice for seed provides for a uniform ripening of seeds on the main and lateral panicles, improves plant

resistance to lodging and increases the productivity of the plant stand. All this in turn reduces the risk of blast disease and produces seed of a higher class. In addition, this method allows for easy weeding to maintain varietal purity and identity of seed by removing off-type and other crop plants from the field.

The time to sow rice for seed is equally important. Early seeding results in a thinned stand establishment during emergence, while with delayed seeding the seed usually fails to fully mature and, as a result, exhibits poorer germination.

Seed rice plantings require optimum levels of nutrients, particularly phosphorus. Excessive applications of nitrogen fertilizers should be avoided because high nitrogen content delays maturity, especially when the weather during the growing period is cool and rainy. In addition high nitrogen weakens the strength of the stem of the rice plant which leads to severe lodging, which results in poorly filled grain, high spikelet sterility, problems at harvest time, and germination in the panicle.

Insofar as possible, seed fields should be managed so as to minimize lodging and produce satisfactory yields without excessive vegetation growth. This is impossible with high single rates of nitrogen, which must be applied in divided or split dressings. In seed fields ammonium sulfate and urea are preferred over all other sources of nitrogen.

Phosphorus fertilizers appear to improve seed quality. Depending on the forecrop and degree of soil salinity, phosphorus is applied as basal at rates from 90 to 150 kg P_2O_5 per hectare before seeding. Potash is also essential for seed fields to facilitate maturity, obtain well-filled grain, and reduce the percentage of empty spikelets. Potassium is usually applied as a topdressing during leaf-tube formation (the 8-9-leaf stage) at 30 to 60 kg K_2O per hectare.

The Control of Red Rice

The use of specific varieties that differ in maturity, grain type, processing and cooking qualities of rice grain have increased the possibility of seed mixing. In this respect, the production of seed that is varietally pure and free of persistent weed seeds becomes extremely important. Preventing intermixing throughout the various phases of seed production requires very close attention by the grower. Commercial varieties could become badly mixed with other varieties and infested with weedy strains of rice. These strains are the red rices that reduce grain and milled yield during harvesting and processing.

All the strains of red rice are characterized by severe shattering, rapid growth, high yield, and a tolerance to adverse environments. Red rice produces many tillers (up to 60), and the progeny from one seed may amount to 1500-1600 viable seeds. Usually, the grower inadvertently spreads red rice by planting contaminated seed. Because herbicides do not selectively control red rice in the rice crop, infestations should be removed from seed rice fields by other methods if one is to avoid deteriorated quality in seed rice and prevent further spreading of the weed. Red rice contaminates not only the seeding material but also the soil. Tests have indicated that without proper weeding, the quantity of red rice in the seeding material the following season increases 5 to 10-fold.

To control red rice it is necessary to know the biology of its strains. Control is difficult yet possible through crop rotations, weeding operations, renewal of seed sources, adequate tillage, etc. Red rice infestations of soil can be prevented through using land cropped with perennial grasses, seeded fallows and new riceland for elite propagation and seed rice fields. Red rice plants that appear in the first year alfalfa crops following rice do not produce seed because they are cut out with each cut of alfalfa for hay.

Red rice seeds shed into the soil remain viable for several years, and are able to sprout from a soil depth of 10 cm. Thus the emergence of a red rice seed plowed under in the fall to depths of 2 and 10 cm would be 20 to 10 percent, respectively. All plants that emerged would develop well and produce seed.

Flooding or flushing the soil to provoke red rice emergence is an effective means of red rice control. The method is particularly useful in cultivated fallows where a flood is established after the fallow-grown crop has been harvested to soak the soil to refusal. The weeds and volunteer rice plants are then killed by disking or working the field over once with a chisel or plow. Besides mechanical eradication of the soil-borne red rice, use of high-quality seed rice that is free of red rice and other weed seeds is an effective way of controlling repeated infestations.

Red rice infestation increases without regular rogueing of seed fields, or when rice follows rice continuously. Infestation will also increase if the grower relies on his own seed stock for several seasons, or if the seeding material is badly mixed.

Seed rice fields should be rogued several times during the last part of the growing season to eliminate not only the red rice plants but also the mixed varieties or rogues. The first rogueing is done at tasseling when the panicles of the early rices are visible. The second rogueing is initiated when the seed rice variety has fully developed and the rogues can be

checked for the absence or presence of awns and coloration of the panicles. All awned plants are then removed from the seed fields growing awnless varieties of rice and, conversely, all the awnless plants are removed from the fields growing awned varieties.

Length and diameter grading of seed rice has been extremely useful in removing the larger diameter red rice grains from the seed of long-grain varieties. The use of such graders is important in controlling red rice. In the medium-, and short-grain varieties, the only means of red rice control is the use of seed and land which is free of red rice because no method of separation has as yet been devised. The propagation of seed containing red rice soon results in a wild infestation of the soil with red rice strains and further complicates the maintenance of pure seed.

Field inspection of seed rice fields by the Seed Certifying Agency is carried out 5 to 6 days before harvest time to establish the varietal purity and identity of seed rice and to note the degree of infestation with red rice, diseases and pests. Where required, one additional rogueing may be recommended. Field inspection together with laboratory analyses of seed samples are used for further seed certification. In order for the rice to be eligible for certification, the seed rice has to satisfy specific requirements and standards which are available from an official certifying agency. In general, these requirements deal with application procedures, field and harvest inspections, post-harvest seed movement, seed processing and sampling. All rice growing areas use these standards as the minimum requirements for seed rice.

The Time and Method of Harvesting Seed Rice

The time and method of harvesting seed rice are both important as they influence seed quality. The practice of water management in seed crops is equally important. Drying the fields for harvesting requires the close attention of the grower. Care should be taken when drying a field that the water recede gradually, e.g., at a rate of 1 cm per day. Day-to-day observations have to be carried out over soil which is drying in areas where rice seed is not dormant and able to swell and germinate in the panicle. If this is the case,the depth of water in the rice paddy should be lowered immediately to a minimum and, in low-lying areas, withdrawn completely. To be of high quality seed rice must be harvested at the proper stage of maturity. If the seed crop is cut when immature, field yields are reduced and

the breakage in threshing is excessive because of the light and chalky kernels. If the seed crop is left in the field until overripe, the kernels may check.

The difference in moisture between the inside and the outside of the kernel is said to be the cause of checking, or shattering of the grain. When too much moisture is removed due to high temperatures, stresses and strains occur in the kernel which result in the microcracking of kernels. The checking of rice depends also on the shape of the grain, the degree of maturity, the variety, and growing conditions, but the moisture content still remains the decisive factor. Insofar as the checking of rice is not only the result of the outside (weather) factors, but also of the mechanical impact it receives during threshing, cleaning, artificial drying and grading, it is best to employ a method of harvesting that will result in seed with minimum damage percentage. Two-staged threshing from the windrow is the preferred method during harvesting seed rice to reduce mechanical damage. The combine threshes about 80 to 85 percent of the grain for seed during the first pass. What is left is threshed during the second round. The USSR RRI tests confirmed by practical observations of growers have indicated that the least losses occur with double-stage threshing in which the speed of the thresher cylinder during the first pass (peg-tooth cylinder 550 rpm and raspbar cylinder 750-780 rpm) is slower than during the second pass (700 and 1 000 rpm, respectively).

Harvesting should not be started until 90 to 95 percent of the grain in the panicle are fully mature. This is established by taking an average sample. Seed rice should be harvested within the shortest time possible and with a minimum interruption between cutting and threshing. The normal procedure is to cut rice, let it stay in the windrow for 3 to 5 days to dry, and then thresh it from the windrow. Leaving the windrows in the field is unadvisable because of adverse weather factors that may cause the grain to check and lower its quality. Where the two-staged harvest method is used for different varieties, threshing should by all means be done with thoroughly cleaned combines. To keep varieties segregated use is also made of direct combining where the rice plants are not very badly lodged and the grain yields do not exceed 5 t/ha. In such cases the drying of the grain can be promoted by applying such chemical desiccants as magnesium sulfate which has proved useful in seed fields in tests conducted in various rice areas about the country. Spraying magnesium chlorate at 25 kg/ha (active substance) hastens the drying of the grain and straw by 10 to 12 days. This practice prevents lodging, reduces by 10 to 15 percent the checking of kernels, and permits direct combining. No grower, however, should use a desiccating material on the maturing seed crop until he has checked its legal status with reference to chemical residue tolerances.

Processing and Storing Seed Rice

Drying, Cleaning and Grading

The seed with a high moisture content rapidly heats. This activates physiological processes within the grain and causes mold growth and lowers seed quality. Seeds with a moisture content of about 15-15.5 percent remain dormant, i.e. they do not show the original capacity to germinate for 15 days. Seeds with a 16-17 percent moisture content remain dormant for 7 days, and seeds with 18-19 percent moisture — only for a day. The dormancy period of a viable seed can extend until the following season without spoilage only when its moisture content is not more than 14 percent. During storage, however, the grain moisture content is likely to increase. Therefore, the moisture content of the seed put to storage must be brought to 13 percent through natural or artificial drying. Sometimes, natural drying of seed in the windrows, in a static bed in the sun at the receiving grounds, or by turning it through grain throwers is enough to bring moisture to the standard. More often, however, resort must be made to artificial drying of the rice with heated air in the grain bins or in other types of storage facilities which are equipped for this purpose with forced-draught fans. Occasionally, heated air may be used, depending on the weather conditions.

For proper drying of seed rice, moisture must be removed from inside the kernel. This should be done slowly to prevent internal checking or breaking of the kernels. Seed quality is satisfactorily preserved when the drying is done with a grain drier in several stages. In each stage, the grain passes through the drier, then is tempered in a bin for 8-10 h so that the kernel's moisture will equilibrate. The air-drying temperature should not be so high as to injure seed rice, yet sufficient enough for the moisture content to be reduced by about 2-2.5 percent at each drying operation.

Cleaning seed rice is an exacting operation that requires specialized equipment. The first step in the cleaning and grading process is to put rice through a fanning mill to remove sticks, stems, mud lumps, weed seeds, hulls and other light-weight foreign material. The second step is a grain-length separation process that may be done with a disk or indented cylinder-type machine. The third step is a process of diameter or width separation. For this purpose a vertical screen or a perforated cylinder grader with rectangular slots 2.2 × 20 and 2.0 × 20 mm in size can be used. As was mentioned earlier, the length and diameter grading of seed rice is very useful in removing the larger diameter red rice grains from the seed

of long-grain varieties. To avoid breakage it is advisable to sacrifice the efficiency of the grader for quality.

Storing Seed Rice

The condition in which seeding material reaches the grower is very important. Conditioning seed requires great care and attention by the producer during all seed processing operations, transportation, and storage. Unlike the seed of most cereals, seed rice during storage is problematic due to the high content of fats in the embryos and the high hygroscopicity of the seeds. The time during which rice preserves its viability during storage depends largely on seed moisture and temperature the optimum levels of which are 13 percent and 0°C, respectively. In laboratory and field germination tests, seed rice showed good results under such storage conditions, and was able to retain its viability for over twelve years. Temporary storage of new seed with a moisture content above 15.5 percent requires that the temperature of stored rice be maintained about 7 to 10°C. Such a temperature range is safe for retaining viability during 6 to 8 months. The viability of stored rice may, however, vary with the variety. To avoid overheating and remove heat it is necessary to aerate seed rice at regular intervals and cool it during the winter. Aerating rice seed is used to remove small amounts of heat and is a recognized method for maintaining the quality and market value for all lots of seed when the air temperature is lower than the seed temperature. Aeration is defined as the passage of air through stored rice. Low ventilation is used only at night during the summer, and both night and day when the weather is cool and dry. Sack storage is the most practical method for storing seed rice. Rice in bulk storage should be turned once every 2 months during the winter and at least once during the summer. Turning can be achieved with the help of belt conveyors, cleaners or grain throwers. A static bed up to 2 m in the winter and 1-1.5 m high in the summer is considered safe in bulk storage for seeds with a standard moisture level of 13-14 percent. With sack storage, 4 and 6 sacks per pallet are satisfactory for storing rice in the summer and winter, respectively.

Seed rice is usually stored when dry. At times, the need may arise to store undried rice until it can be moved through a drier. Aeration or subnormal temperatures are used in such cases to maintain the quality of the undried seed rice. The results of storage experiments and practical observations indicate that although temperatures — 10 to − 12°C do not influence germination of rice with a moisture content of up to 15 percent, it

is best to avoid temperatures below 3 to 0°C in storing damp (above 15 percent) seed rice. In bulk storage, accurate temperature control is mandatory for maintaining the quality of damp rice. This can be done with temperature recorders placed at different levels of the static bed of rice. Mechanical turning or forced ventilation is used to cool down the damp rice to a safe storage temperature. The seed certifying agency carries out laboratory germination tests at least twice a year (in the fall and spring) to control seed quality while in storage.

The length of the seed storage period can be extended by maintaining the storage temperature at 0 to 10°C. At zero temperature, the seed retains Class I viability for 6 years, at 10°C, for 2 years. To facilitate sprouting energy, the seed may be aerated with warm (heated) air or spread in a thin bed in the sun, or otherwise processed, 5 to 10 days before it is sown in the spring.

The current tendency in this country has been towards setting up a specialized seed industry which would include carefully selected growers, seed-growing organizations equipped with modern field implements, machines, seed specialists, and storage structures all of which would keep the seed dry, cool, and free of insect and other pests of rice, as well as provide job safety and convenience when moving and inspecting the grain.

9

VARIETIES OF RICE

Growing new, superior varieties is a decisive factor in high-level crop production. From a purely economic viewpoint, varieties put to equal conditions are known to produce different yields. So by choosing a superior variety to replace one grown earlier the grower may gain about 0.2 t/ha more rice without any additional input.

The varieties earlier grown commercially in Central Asia and Transcaucasia were primarily rices introduced long before from Iran, although some were old local varieties of rice. Early-maturing rices, such as Kenzo, Olbe, Hokkaido, and Bozu from Japan, and Dunghan Shali, were grown for quite some time in the newly developed lands on the Kuban and the Don rice-growing farms. Japanese and Korean rices were primarily grown in the far-eastern rice producing areas of the USSR.

To meet the need of practical rice farming the Soviet breeders have developed new early-season varieties that are superior in yields, resistant to lodging, diseases, and shattering. These new rices can produce upwards from 7 to 8 t/ha of paddy rice provided advanced cultivation practices are used and proper management employed. That rice has advanced further north to areas where no rice of foreign selections is capable of being commercially produced also is to the credit of the Soviet breeders.

There are 27 principal commercial varieties of rice in this country 14 of which are grown in the Russian Federation only. The largest acreages are sown in Krasnodarsky 424 and Kuban 3. For present purposes, a brief description of the principal commercial and recommended varieties is appropriate.

Description of Selected Varieties

Commercially produced rices. KRASNODARSKY 424 (*O. sativa* var. *italica*) was developed at the USSR RRI (the former Kuban Rice Field Station) in 1956 by crossing Krasnodarsky 3352 with Kenzo. It is late mid-season (120-125 days), high-stem (120-130 cm), and lodging resistant. It is one of the best domestic varieties of rice that heads and matures uniformly in 9 rice areas of the Northern Caucasus, Ukraine and Azerbaijan, and produces high yields that exceed 7.5 t/ha. In 1983, 265 600 hectares were sown in this variety which accounts for 40.1 percent of the total rice acreage in the country. In yield tests conducted in 1968, its average yields were 7.44 t/ha in the Kuban area, 7.18 t/ha in the Crimea (the Ukraine), and 10.87 t/ha in the Sarpa bottomland rice area (the Cis-Caspian Lowland). When milled, it yields 69 percent total milled rice 90 percent of which are whole-grain kernels or head rice, and 17 percent are bran and polish (huskiness). Its round, vitreous grain contains 7-8 percent protein and 90 percent starch of which 24.5 percent is amylose and shows good table quality: the cooked rice varies in color from white to light-brown and gives non-sticky, separate grains. Its palatability scores 4-5 points (a 5-point scale), water uptake 140-150 percent. Germination is prolonged and non-uniform. Seedling vigor is low when sprouted through a depth of water. At emergence it needs high temperatures. At mid-tillering, growth vigor increases and plants look strong and rigorous. New riceland, grassland and cultivated fallows are the best rotational fields for this variety. Higher rates of nitrogen (up to 180 kg/ha) are recommended to grow rice following its first year, along with herbicides to control grass weeds. Krasnodarsky 424 has been for many years and still is the most popular late mid-season variety of rice in the USSR.

KUBAN 3 (*O. sativa* var. *zerovschanica*) originated as the single plant selection at the USSR RRI from the variety Krasnoarmeisky 313. The seed of Kuban 3 was distributed in 1963. It is mid-season rice (maturity period 105-115 days), maturing 10-12 days earlier than Krasnodarsky 424, 105-120 cm tall, and badly lodges when the crop is heavy.

The plant requirements are not unusual and the variety has the potential of producing high yields (9.3 t/ha in some years). At yield tests, it produced 6.0-6.5 t/ha in the Northern Caucasus, 5.5-6.0 t/ha in the Ukraine. In 1983, commercial plantings of Kuban 3 accounted for 197 000 ha and were located in 4 rice-producing areas. Processing and cooking qualities of this rice are inferior to Krasnodarsky 424. The milling yield of total milled rice is 67 percent, although it is 71 percent in the Northern Caucasus. Huskiness is 17 percent. The grain is vitreous. The milled kernels contain 8 percent protein and 90 percent starch which is inferior to that of Krasnodarsky 424. In cultivation the seed of Kuban 3 is noted for its high field germination and uniform emergence. Unlike other varieties it needs less warmth at sprouting, which can start at comparatively low soil and water temperatures. Kuban 3 shows good stand establishment with plants emerging through large depths of floodwater. It responds readily to soil nitrogen, and when nitrogen is excessive it develops much vegetation, but its straw is weak and thin. Where conditions are favorable for lodging the end result will be empty spikelets and shrunk kernels. High rates of nitrogen (more than 110 kg/ha) applied to fertile soils cause bad lodging and reduce yield.

Recommended varieties. SOLNECHNYI (*O. sativa* var. *italica*) was developed at the USSR RRI as a single plant selection from the USSR RRI specimen 3320 obtained from the Ardisone (VIR 4540, Italy) × line (VIR 2157 × Dubovsky 129). It is an early mid-season (maturity period 81-101 days), medium-stem (66-80 cm) variety of rice with high resistance to lodging and shattering, and moderate resistance to blast. It is awnless, and has a short, compact panicle. The oval-shaped white grain is 16-27 percent more vitreous than standard varieties (vitreousness 85-93 percent). Its palatability is excellent. The 1 000-grain weight is 29-31 g; huskiness, 17-18 percent. Milling quality is satisfactory; yield of total milled rice is 67-68 percent, of head rice 66-84 percent. During competitive trials, it yielded from 6.7 to 7.2 t/ha, i.e. 0.35-0.49 ton more than standard varieties, and during a pilot production test it yielded 6.51 t/ha.

START (*O. sativa* var. *italica*) originated as a single plant selection from a hybrid of unknown origin. The seed was distributed to the Kuban area farmers in 1980. It is an early mid-season (103-112 days), short-stem variety that mills and yields fairly well. Its thick, erect stem bears a small

(11-14 cm) but compact panicle that may produce from 70 to 100 spikelets. High rates of fertilizers add little to the height of culm (80-85 cm) but increase the number of kernels in the panicle. The seed shows good germination but stands are thinned (by up to 30 percent) where seedlings must emerge through deep floodwater. Consequently, the plant heads and matures 5-7 days later. High rates of nitrogen (180-200 kg/ha) cause excessive tillering resulting in a number of laterals (tillering coefficient 2.9-3.8). A seeding rate of about 6 million viable seeds per hectare is therefore desirable. In yield tests, Start produced an average of 7.08 t/ha of paddy rice, or 0.7 t/ha more than the standard Kuban 3. The variety has superior lodging resistance, good salt tolerance, and a satisfactory milling quality. The 1 000-grain weight is 30-32 g; vitreousness, 82-92 percent; huskiness, 18 percent. The yield of total milled rice is 68-70 percent.

SPAL'CHIK (*O. sativa* var. *italica*) was developed at the USSR RRI as a single plant selection from a hybrid population of Balilla a Grana Grosso × (Krasnodarsky 3352 × Kenzo). Spal'chik is a mid-season (maturity period 114-116 days), strong-stem, foliated variety that is resistant to lodging. Its stem height ranges between 70-80 to 100 cm, depending on growing conditions. The plant is compact in habitus. It forms tillers uniformly along its stem with a tillering coefficient of 2.6 in warm years and 1.5 in cold years. Heavy fertilization increases growth and the grain/straw ratio does not tend to exceed 0.7-0.9. Its short, compact panicle bears from 90 to 100 spikelets. Their number may be increased to 120-130 when the variety is sown early in soils which are heavily fertilized with nitrogen (180-200 kg/ha, active substance). The average 1 000-grain weight is 28-30 g. Spal'chik yields and mills well. Yield of total milled rice constitutes 71.2 percent, huskiness, 16.7-17.5 percent. The grain is vitreous. The variety as a whole is resistant to shattering; its seed shows good germination at temperatures from 11 to 14°C, but cold temperatures at tube-formation and flowering increase floret sterility to 20 percent or more, which in good years is only about 11-12 percent. In performance tests, Spal'chik proved to be salt tolerant. Treatments with amine salt, however, increase the number of empty spikelets in the panicle to 18-20 percent, unless the herbicide is expertly timed and rated. Propanil delays growth and development of Spal'chik and the result is poor yields due to a reduced number of tillers and spikelets in the panicles. High yields (9-10 t/ha) require good, fertile soil and clean fields. Spal'chik responds well to higher rates of nitrogen (up to 200-220 kg/ha) which increase the number of productive tillers and, in an early-seeded crop, reduce the number of empty spikelets. For this reason, recommendations to the grower are to plant this variety as early as possible to provide 2 320-2 380°C degree-days from seeding to maturity.

Average yields in 1976 varied from area to area between 7.3 to 7.66 t/ha. In 1978, the variety yielded 10 t/ha. Its acreage in 1983 was 3 800 hectares.

SOLARIS (RASSVET) (*O. sativa* var. *nigroapiculata*) originated at the Ukrainian Rice Station as a single plant selection from a hybrid population of Balilla Triumph × Dubovsky 129. Released to farmers for growing in the lower reaches of the Volga, Solaris is an early-season, lodging-resistant rice that produces grain with good milling and cooking qualities. It is an awnless, short-stem (73-86 cm) variety with a short, slightly spread panicle bearing spikelets with tips that are dark-violet to almost black. The grain is 5.6 mm long, 3.1 mm broad and 2.1 mm thick. The 1 000-grain weight accounts for 33 g. Its huskiness is about 17-18 percent. Vitreousness is 86-89 percent. The yield of total milled rice constitutes 68-79 percent, that of head rice, 95 percent. When cooked, the rice is light and creamy and scores 4 points by the 5-point palatability scale.

In yield tests (1977-79), it produced 5.81 t/ha, or 0.28 t/ha less than the standard variety Kuban 3. In 1978, a much cooler year, Solaris produced 6.24 t/ha due to its early ripening ability, or 1.55 t/ha more than the standard Kuban 3.

MALYSH (*O. sativa* var. *nigroapiculata*) is a single plant selection from the mutant M 200 230. It was produced by treating Sirayuki with ethyl methane sulfate at the 20:0.5 exposure. It is an early-maturing (110-112 days), short-stem (66-74 cm), awnless variety that is resistant to blast due to its shorter culm, is also resistant to lodging, and to shattering, and thus is suitable for direct combining. The plant has a compact compressed panicle. Its leaves are straight, long and narrow. The white vitreous grain is 5 mm long, 3 mm broad, 2 mm thick, and is hairless or only slightly pubescent which distinguishes it from other rices. Malysh responds readily to high rates of nitrogen (120 kg/ha) and can be deep seeded. It germinates and emerges uniformly and heads and matures well. It yields satisfactorily. In 1978, it produced an average of 3-3.5 tons in one area, and 7.02 t/ha, in others. It mills well and has good cooking quality. The yield of the total milled rice is 68-70 percent. The grain is crush proof and the yield of head rice is hence 99.6 percent.

Choosing the Variety

Several factors go into choosing a variety. They include a satisfactory yielding ability, the proposed seeding date, location, soil fertility, anticipated cultivation and fertilizing practices, relative maturity, susceptibility to diseases, and seed supply. Growers in certain localities may be

restricted to growing only rices that belong to one maturity group. Varieties that mature within 110 days are considered early season; within 125 days, mid-season; and others are late-maturing rices. Depending on the area and climate, the maturity period of any given variety may vary. Rices that mature within 110 days in the Kuban area (early varieties) will mature from 8 to 10 days later in the Far East. The best results can be obtained only by growing varieties that are well adapted to the environmental conditions of the given locality.

In choosing this variety, preference is certainly given to those rices that will permit the rice crop not only to ripen but also provide the grower sufficient time and good weather to harvest the crop over large acreages and complete all the post-harvest field operations necessary for the following season. Growers in the northern part of the rice-growing areas, e.g., the Sarpa bottomland, are limited to early-maturing varieties that have to be salt-tolerant, lodging-resistant, tolerable to the cool night temperature that occurs early in the season and that produce no less than 5.3-6.0 t/ha of rice within 115-120 days. Among such varieties are Solaris, Malysh, Solnechnyi.

In the European USSR and the Far East, the short frost-free period, adverse weather at harvest time and large acreage in rice makes it desirable to choose two or three varieties that differ in maturity period since standing rice maintains its highest biological yield for 10 to 15 days only. This may pose real problems at harvesting large acreage sown to one variety. Where rice production involves a large acreage, the land should be divided between several varieties of rice that will mature and be ready to cut at different dates in the fall or, where large acreages are sown to a single variety, the seeding dates should be spread out in order to ease the time pressure at harvest time. Harvesting will thus proceed gradually from field to field as the crop matures preventing grain losses and premature germinations in the panicle. It will also help ease difficulties in distributing labor and equipment between harvesting and land preparation operations for the following season.

In the Soviet Union, the primary objective in rice breeding is to develop varieties that will assure maximum and stable production of the types of rice required by growers and consumers. Emphasis is put on developing short and medium-season varieties. In addition to high yielding, short grain types, long-grain varieties, which are highly esteemed by the consumer, have to be soon released to the growers for commercial production.

Generally speaking, the objectives of most breeding programs are to develop varieties of rice that:

(1) germinate rapidly and grow fast in the seedling stage;

(2) tolerate low temperatures in the germinating, seedling, and blooming stages;

(3) are tolerant to saline and alkaline soils as well as salts in flood water;

(4) are resistant to diseases and pests;

(5) have shorter, stiffer culms to resist lodging;

(6) respond readily to and make good use of maximum rates of fertilizer;

(7) mature uniformly and produce seed that has a dormancy period and will not germinate in the panicle when harvest is delayed by adverse weather or other reasons;

(8) produce maximum field and mill yields;

(9) have maximum protein content;

(10) have the desired processing and cooking qualities required by the market.

A variety will realize its optimal potential only when its environmental requirements are fully met and recommended cultivation practices as specified by the breeder are expertly executed.

References

1. Roschevicz R. J., [A Contribution to the Knowledge of Rice] *Bull. Appl. Bot. Genet. Plant Breed.* (Leningrad) 27 (4): 3-133 (1931) (in Russian, English summary).
2. Gushchin G. G., *Rice* (Moscöw: Selkhozgiz, 1934) (in Russian).
3. Sokolova I. I., *Flora and Fauna* (Leningrad: Kolos, 1975) (in Russian).
4. Velichko E. B. and Zyryanova M. I., *Controlling Precision of Surface Leveling in Rice Fields* (Krasnodar: Krasnodar Book Publishers, 1979) (in Russian).
5. Kirichenko K. S., *Information Bul.* (Krasnodar: VNIIR, 1971) (in Russian).
6. Neunylov B. A. [Biological Grounds for Rice in the Far East] *J. Gen. Biol.* No. 4 (Moscow, 1974) (in Russian).
7. Smirnova N. N., *Improving the Efficiency of Fertilizer in Irrigated Farming* (Moscow: VNIITEISKh, 1979) (in Russian).
8. Aleshin E. P., Aprod A. I., and Konokhova V. P., *Methodical Recommendations on Improving Rice Quality* (Moscow: Kolos, 1980) (in Russian).

THE IRRIGATOR'S PRACTICAL GUIDE

Month		April	May			June			July			August			September	Note
Decade		3	1	2	3	1	2	3	1	2	3	1	2	3	1	
Phase of development		Seeding, submerg	Germination		Emergence		Tillering		Leaf-tube, heading			Flow-ering	Ripening			
Length of phase, days		10	15-20		15-20		25		25			7	33			120-130 days
Leaf-stage			Coleop-tile	Awl	1 2	3 4 5	6 7	8 9	10 11 12			Panicle	Soft-dough	Hard-dough	Fully mature	Variety Krasno-darsky 424
Shooting of laterals							1 2	3 4 5								
Optimum values of yield parameters		Stand density, 250-300 plants per m²					Productive tillers: 2-3 stems	Number of kernels: 110-130 grains/panicle	Empty kernels, %: Not more than 10% empty spikelets				1000-grain weight 28-32 g			
Optimum irrigation	Depth of water, cm	10-12	Moisture to field capacity, short-time drying before herbicide treatment					25-30	15				15- 10		0	
	Thou m³/ha	3.0-3.5			3.0-3.5		3.5-4.0		4.5-5.0				1.5-2.0			Total 16.0-18.0
Optimum temperatures, °C	Average daily	24-28						19-22	24-28				18-26			
	Total for period	520			520		200	300	780				700			3000
Optimum nutrition	Date. Rate of fertilizer application, kg (active substance) per ha	Pre-sowing, N 100, P 200, K, when required		Herbicides to control barnyard grass	1st topdressing N 50		2nd topdressing N 50	Herbicide to control bulrush; 3rd topdressing K 100	Soft- to hard-dough stage; Chemical drying of crop with desiccants							

INDEX

To the Reader

Mir Publishers welcome your comments on the contents, translation, and design of the book.
We would also be pleased to receive any suggestions you care to make about our future publications.
Our address is:
USSR, 129820,
Moscow, I-110, GSP,
Pervy Rizhsky Pereulok, 2,
Mir Publishers

Printed in the Union of Soviet Socialist Republics

Rice Growing

V. Konokhova

The textbook is intended for students of agricultural vocational schools and for training workers — rice cultivators. It describes biological characteristics of rice, its cultivation and harvesting methods, and irrigation systems. Much attention is paid to primary and preplanting soil treatment methods, to harvesting periods and techniques used for various rice-growing machines, and also to the rice-seed growing methods. Economics of rice growing techniques and progressive methods of growing rice are also detailed in the book.